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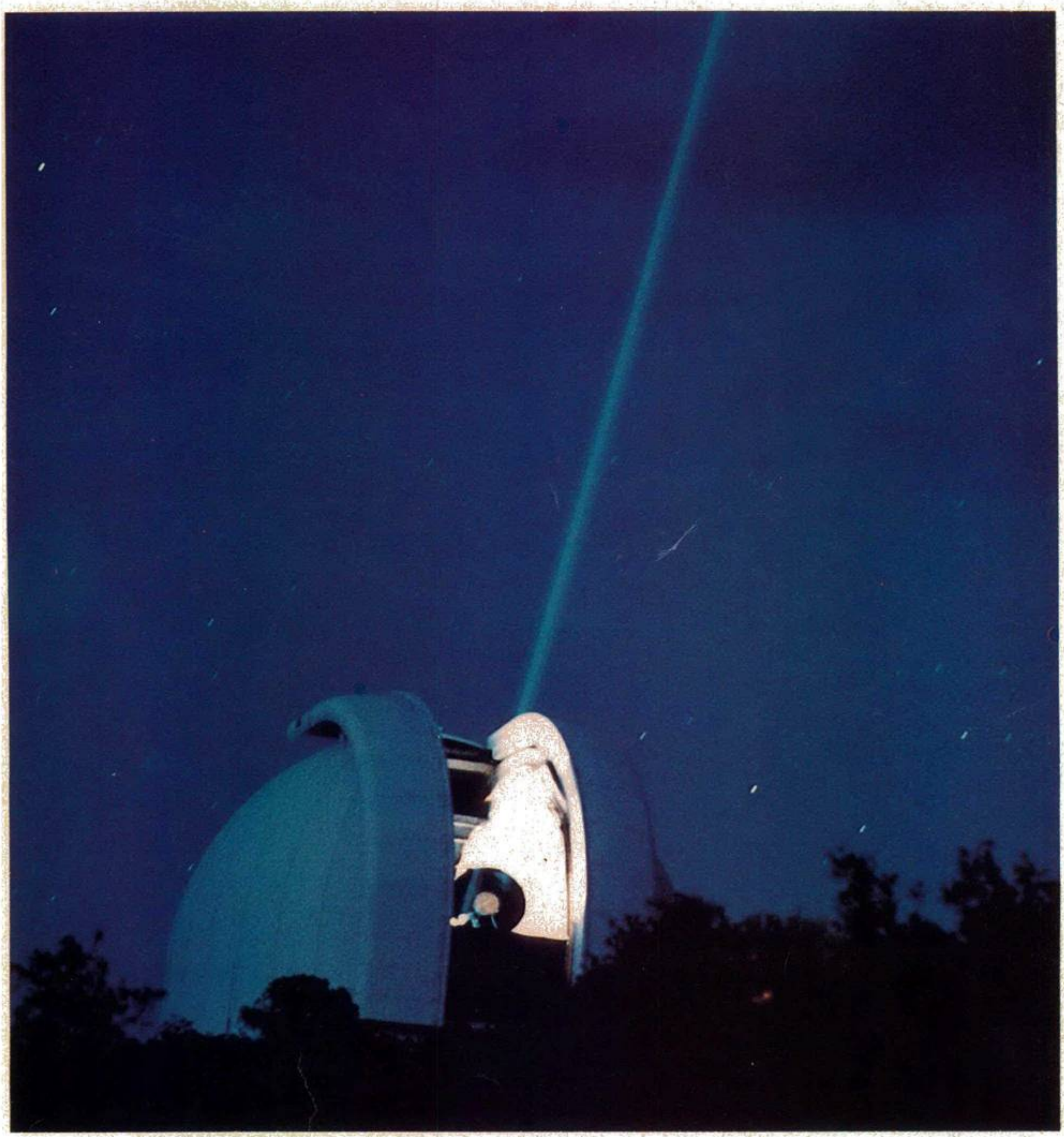

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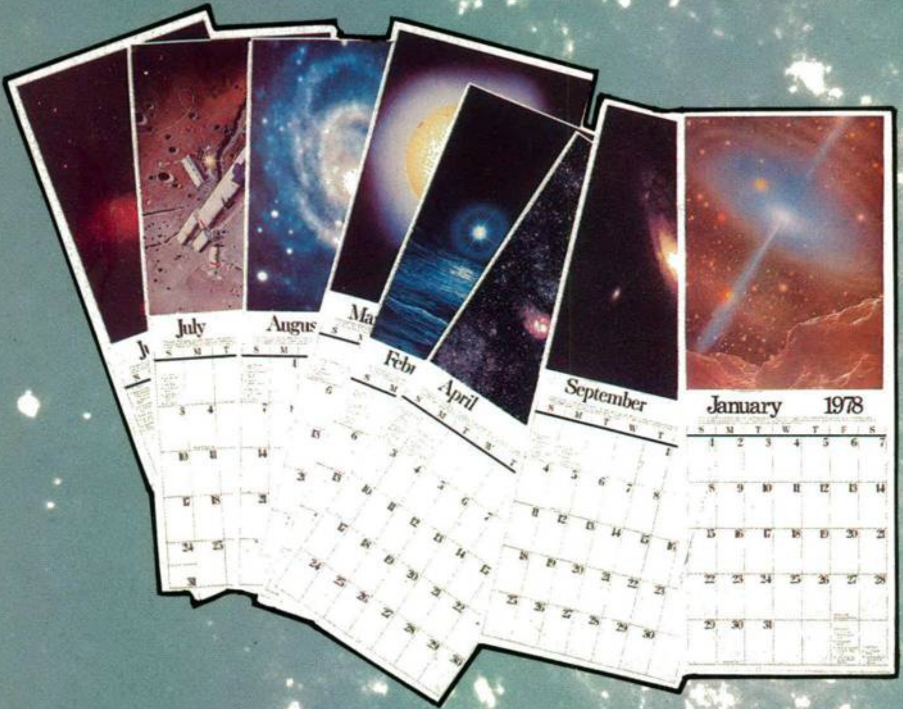

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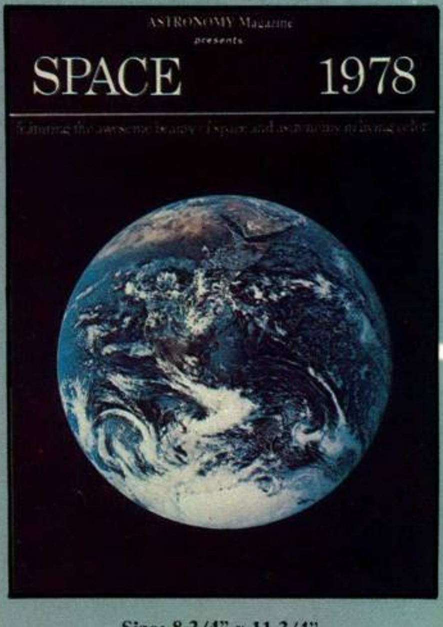

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ASTRONOMY

The World's Most Beautiful Astronomy Magazine

November 1977 Vol. 5, No. 11

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COVER

Reaching out toward the moon with laser light, astronomers at McDonald Observatory near Fort Davis, Tex. continue the lunar ranging program using retroreflecting mirrors (left on the moon by Apollo astronauts) to return the light to Earth. This issue of ASTRONOMY is devoted to a new era in astronomy — an era of big telescopes, satellites, computers and observing from space. Featured are a pictorial survey of observatories and right-from-the-horse's-mouth descriptions from working astronomers which answer the inevitable question: "What's it like to be an astronomer?" McDonald Observatory photograph.

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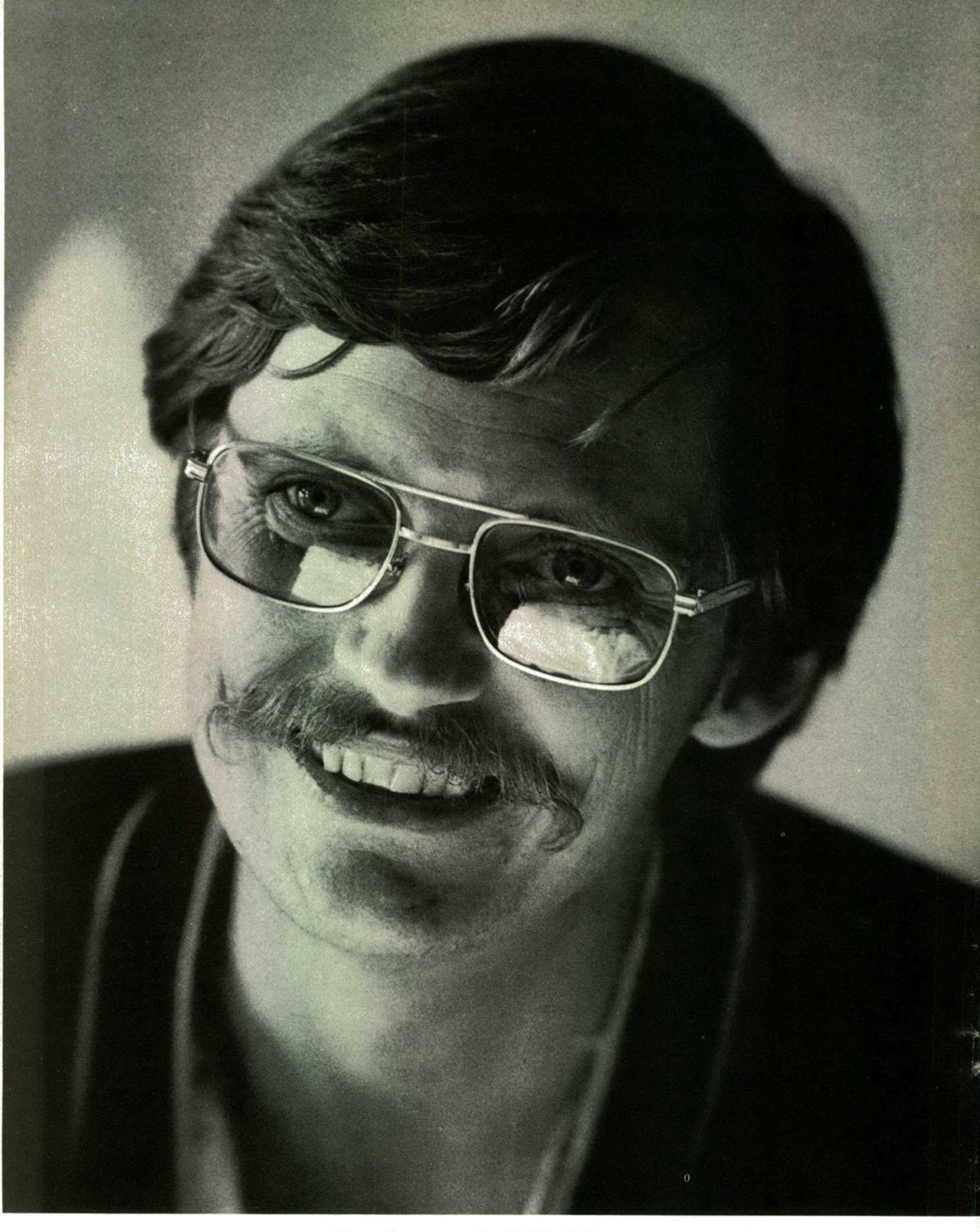


Stephen A. Walther
July 22, 1944 — September 14, 1977

Astronomy compels the soul to look upwards and leads us from this world to another. *— Plato*

Stephen A. Walther, founder and publisher of ASTRONOMY magazine, died of a brain tumor on Sept. 14, 1977. He had been ill for over a year, and away from the magazine on a full time basis since August 1976.

As a bit of background, Steve was born in Stevens Point, Wisc., where he lived until receiving his degree in communications from the University of Wisconsin - Stevens Point in 1971.

He became interested in astronomy while still a child, and was deeply engrossed in observing and astrophotography by the time he was 14. Before long, he was submitting photos to **Sky and Telescope** (some were published). He often recommended **Sky and Telescope** to friends at his star parties and impromptu lectures, but dreamed of an astronomy magazine which would serve a different audience. The seeds of ASTRONOMY were planted.

As a university student, Steve took an independent study course in communications; for his project, he did a feasibility study on the need and potential market for such an astronomy magazine. Through this course, his dream began to crystallize.

Steve wanted to reach laymen who were interested in the science . . . entry level hobbyists . . . amateurs . . . astronomy enthusiasts! He wanted it to be "meaty" and useful to observers, but also a magazine that everyone could get something from . . . be it for "leisure reading" or as a fun educational vehicle. He wanted to "talk with" readers — simply — about this science that has been with us since the beginning of time . . . and will be with us to the end. He planned to emphasize the sheer joy and excitement of astronomy, and the wonders of the universe. And he wanted it to be colorful . . . to share with the world the breathtaking beauty of the universe around us.

Following his college graduation, Steve worked in agency and corporate public relations. It was during this period that his brother David, a Milwaukee attorney, became involved with him in establishing the venture; AstroMedia Corp. was incorporated in September 1972, for the prime function of publishing ASTRONOMY magazine.

The first issue of ASTRONOMY was published in August 1973. Circulation grew rapidly, and as the magazine became more secure, AstroMedia began branching out into calendars and posters, and developed other unusual product ideas.

The original staff of three grew into a highly competent and talented group of 15. And it was this group of 15 that met the challenge and kept producing ASTRONOMY after Steve's brain tumor was diagnosed in August 1976.

Surgery was performed that August; then Steve began the long struggle to return to the office and his duties. Most of the time he worked at home on marketing concepts for ASTRONOMY and AstroMedia, policies and future plans. Early this year, when it became evident he wouldn't be able to return to his full workload, Bob Maas was hired as president and chief operating officer of AstroMedia Corp.

Throughout his illness, his zany sense of humor, courage and optimism seldom wavered. While taking medications that made him sleepy around the clock, he often answered his phone, "Sleepy Hollow, Steve speaking. May I help you?" When he discovered that his tumor consisted of a type of cell called an astrocytoma, he often joked about the irony that he had his very own "Star Wars" going on inside his head.

Steve's condition deteriorated in early July, and he was readmitted to the hospital; tests indicated that the tumor had grown back.

Up to the end, he was eagerly looking forward to his return to ASTRONOMY. Perhaps the following might best describe his spirit and attitude . . . .

Over the years, Steve would often awaken in the middle of the night, and would go outside at 2 or 3 a.m. to do a little observing. On mornings like those, he usually came to the office between 5 and 6 a.m. to work in "peace and quietude" on myriad odds and ends concerning the growth of ASTRONOMY.

Early in the morning of July 27, 1977, unable to walk (but wanting to come to work), he was wheeled the five blocks to the office in his wheelchair. When the staff arrived, the following note was waiting for us:

"Hey there gang —

"I was here before any of you. Does this mean that I've been the only puff of ectoplasmic 'spook' to haunt the hallowed — EMPTY! — halls of ASTRONOMY at 5:30 a.m.?

"Are you *sure* that the Ephemeris doesn't lie? Is Venus *really* the brightest starlike object in the eastern a.m. sky!?

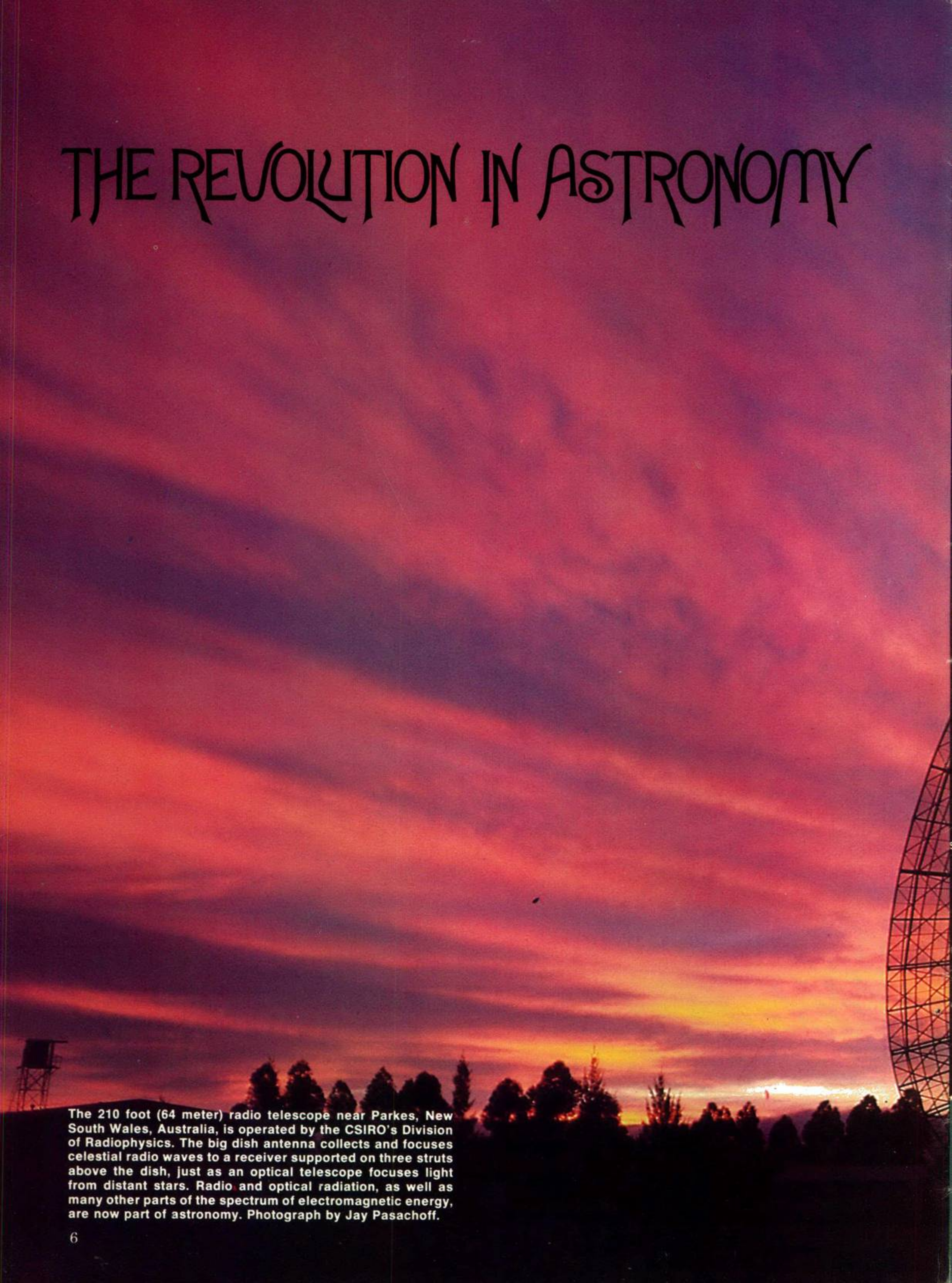
"Boo o o o!"

We will miss him.

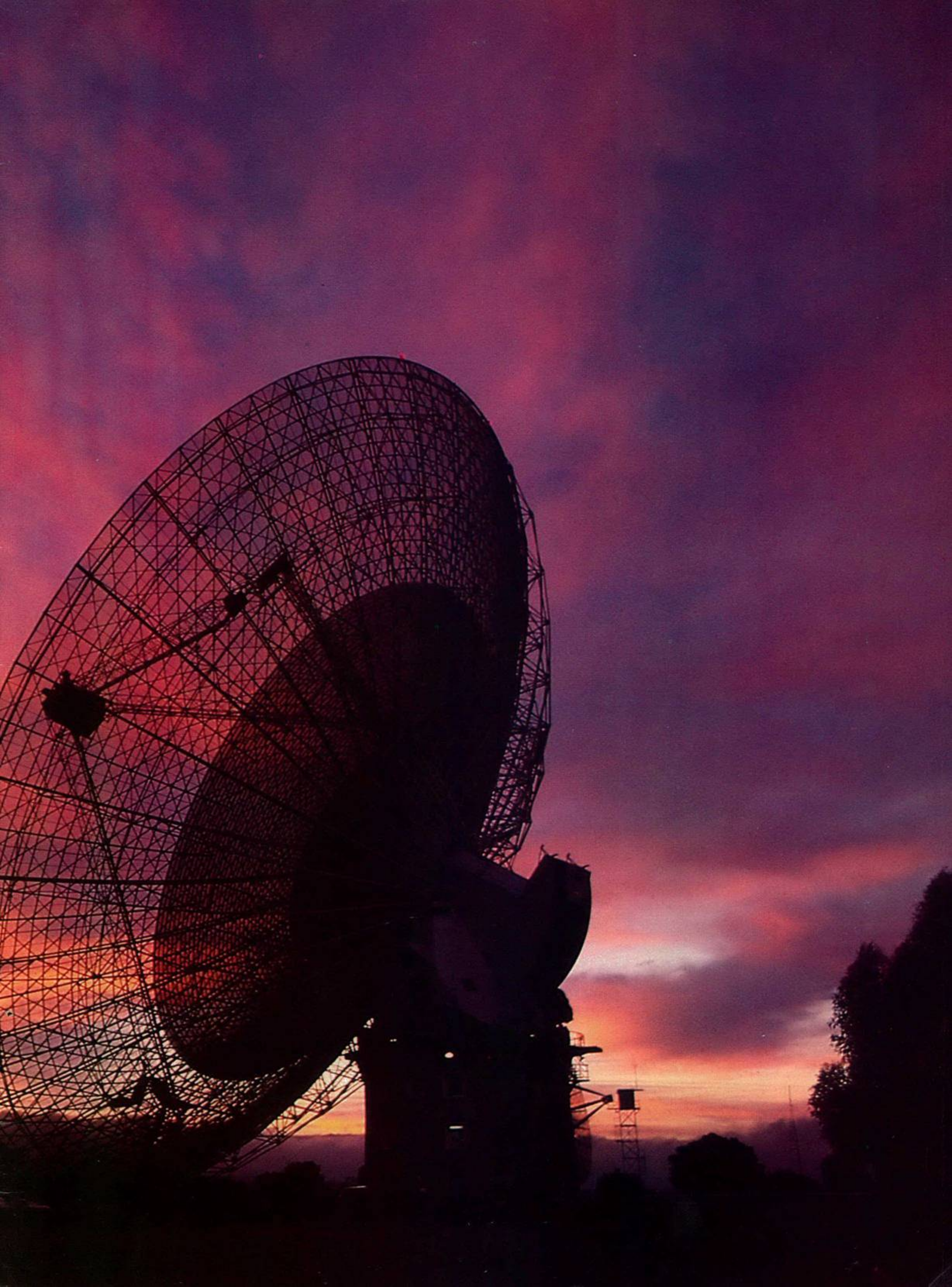
* * * * * *

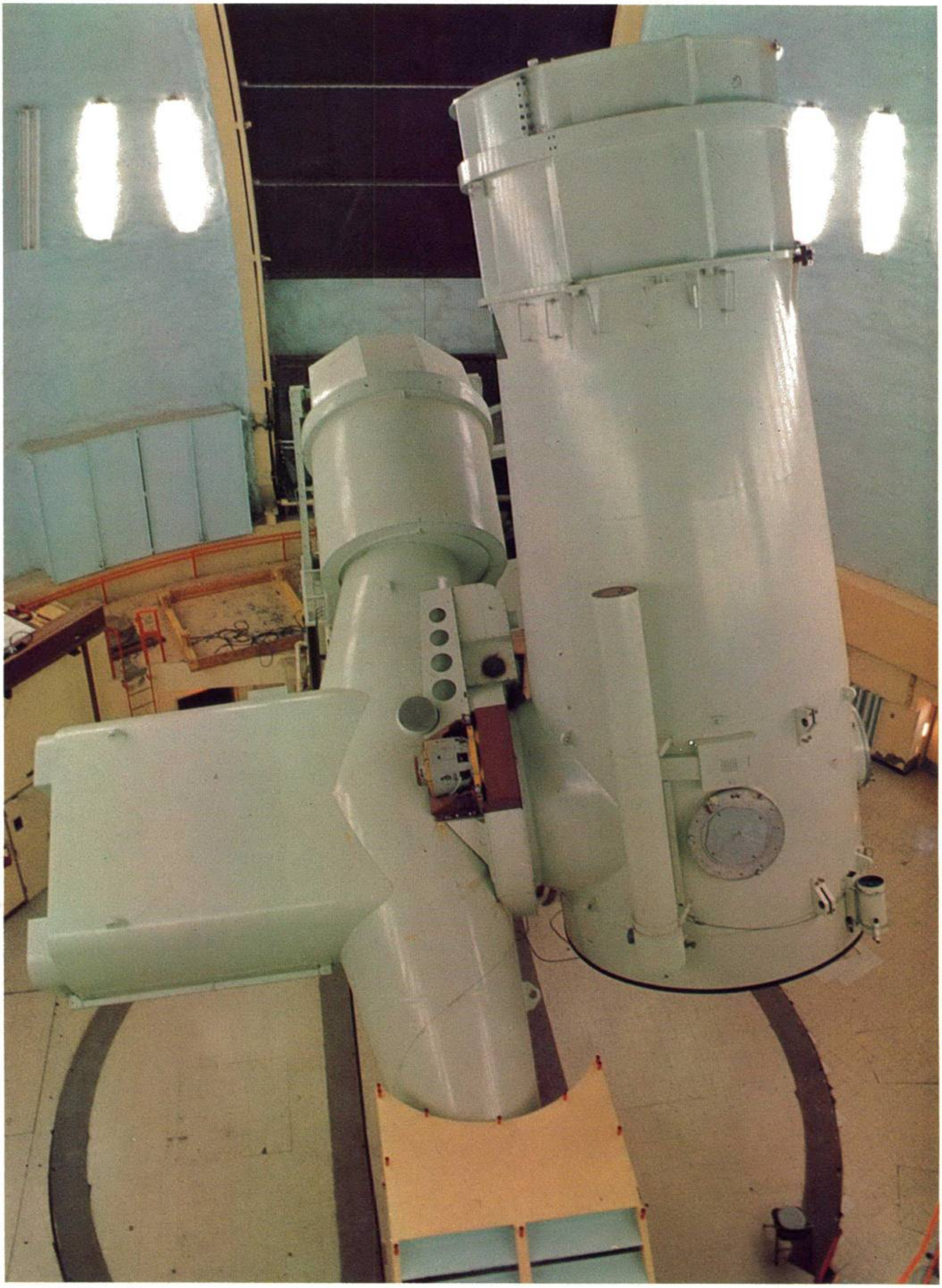
ASTRONOMY will continue . . . a living memorial to its founder.

THE REVOLUTION IN ASTRONOMY



The 210 foot (64 meter) radio telescope near Parkes, New South Wales, Australia, is operated by the CSIRO's Division of Radiophysics. The big dish antenna collects and focuses celestial radio waves to a receiver supported on three struts above the dish, just as an optical telescope focuses light from distant stars. Radio and optical radiation, as well as many other parts of the spectrum of electromagnetic energy, are now part of astronomy. Photograph by Jay Pasachoff.





One of the first of the new generation of giant modern telescopes, McDonald Observatory's 107 inch (2.7 meter) instrument was built to help pave the way for the space age. Part of this telescope's job is to precede spacecraft in exploring the other planets in our solar system. This telescope is seen at work on the cover — sending a laser beam to the moon. Photograph courtesy of McDonald Observatory.

There's been a revolution in astronomy . . . a quiet revolution. Observatories look much the same, and talk around the observer's dinner table sounds much as it did 10 years ago. But there's a difference. Astronomy, which until 20 years ago was done entirely in light visible to the human eye, has expanded into nearly every region of the electromagnetic spectrum, and there's no reason to think that the spectrum revolution will stop. Radio astronomy, infrared astronomy, x-ray astronomy, gamma ray astronomy, space astronomy — these new branches of the science have brought totally new objects into the astronomer's universe.

But that's only half of it. The other half is electronic data processing — something we know in daily life as computerization. Wider regions of the spectrum, sophisticated new radiation detectors, better telescopes, better films, and overwhelming streams of data pouring from satellite observatories — all these would overwhelm astronomers without the aid of computers to sort, store, process and display the raw observational material.

While observational astronomers find themselves making better observations, another type of astronomer — the theoretician — benefits too. While the observational astronomer works to collect information (pictures, spectra, brightnesses, polarization) that allows him to build up a picture of the universe, the theoretician works to produce mathematical descriptions to explain the things observers observe. He may start his work with only pencil and paper, but he'll soon turn to that vital tool, the computer, to help develop a sophisticated understanding of what's out there in space. His theories produce predictions that send the observer back to the telescope to make more observations, which may confirm or overturn that theoretical model in a continuous give-and-take process. The spectral regions opened by new instruments, techniques, and access to astronomy satellites prove invaluable, because checks made in vastly different parts of the spectrum often allow very sharp distinctions to be made between competing models.

Seyfert galaxies, for instance, are a type of "active" galaxy that emit a very unusual optical spectrum from a small bright area in their center, plus lots of radio energy. Theoreticians, trying to develop a comprehensive explanation of what must be happening in Seyfert galaxy centers, predicted that an appreciable infrared energy output occurs. When observers looked, they found the predicted infrared. Now observations have been made in x-ray wavelengths of the Seyfert galaxies which will force theoreticians to recheck their models to ascertain that the new observations are in line with previous models. If they aren't, then it's time for revision.

New Observatories

There's been a revolution in observatories too. Astronomers now insist on placing observatories on mountain peaks — often at great expense and difficulty — in the middle of some of the coldest, remotest, and most desolate locations on Earth! Why? The answer is simple: They want the best performance possible from their telescopes. It's likely to take 20 years to plan, fund and build a major telescope; nothing less than the best place for that telescope is good enough.

Commentary on Modern Astronomy

There are no words to express the feeling of standing alongside and under the great eyes of science, appreciating what they have uncovered about the reality of the universe.

The fact is there is very little eyeball astronomy being done today. Even the photographic plate, the darling of our fathers and present day astrophotographers, has nearly been discarded in favor of the electronic amplification devices and the computer. Talking to telescope technicians allowed me great insight into the role of the modern day astronomer in his quest for data. The need to understand the sky itself is absent. Star patterns are not relevant to his needs. Stars merely represent a factory of ambient physical conditions in which atoms are responding in a manner recognizable by the spectral details in the visual and (most important today) the infrared.

It is one thing to read about it, but it is something else again to see all the equipment set up and operating. It's a totally new era in full blast.

Sherman Schultz, director
Macalester College Observatory

What are astronomers looking for? First, they want isolation from manmade disturbances such as light pollution. Second, they want as many clear nights as possible. The best sites in the world can sometimes offer weeks of flawlessly clear nights in a row (even very sunny climates often aren't that good). Third, they want good seeing (atmospheric stability that permits the mirrors of the telescope to form crisp, clear, untwinkling images). And fourth, they increasingly want dryness. Water vapor absorbs infrared light; dry mountain air transmits much of the infrared. One of the big advantages of infrared astronomy is that much of it can be done in the daytime, so the usefulness of a major telescope

ASTRONOMY wishes to thank each of the many astronomers who searched their personal files to fill these pages with new pictures of observatories. We also thank the observatory directors and their staffs who so willingly supplied the copious background material necessary for this issue. We regret that we could print only a tiny fraction of the pictures received, and feature only a few observatories that we felt to be typical of observatories today.

Allegheny Observatory

Allegheny Observatory has three telescopes: The 31 inch Keeler Memorial Reflecting Telescope, and its associated Mellon Spectrograph, can reach seventh magnitude stars recording their spectra at 40 angstroms per millimeter. The spectrograms yield radial velocities which are used to calculate the orbits of spectroscopic binary and multiple star systems.

The 30 inch Thaw Photographic Refracting Telescope, with a focal length of 46 feet, is one of the largest in the world. This telescope is used for astrometric studies: measuring the positions, proper motions, distances, and orbital motions of various stars and star systems. This telescope is also being used to survey 33 nearby stars for signs of planets in orbit about them. (This is the first such survey ever attempted. See the April 1976 issue of ASTRONOMY for further information on Allegheny Observatory's work in detection of extrasolar planetary systems.)

The third telescope, the 13 inch Fitz/Clark refractor, is over 117 years old, and was used by Samuel P. Langley to make the first accurate determination of the solar constant using his newly invented bolometer. Later, during the 1890s, James Keeler used this instrument in his spectroscopic study of the rings of Saturn. This study proved that the rings are composed of chunks of material in orbit about the planet, rather than being solid as they appear in the telescopic views that we are used to seeing. Since the first decade of this century, the Fitz/Clark refractor has only been used for public viewing of the heavens.

David Dunlap Observatory

The major observing facility of the University of Toronto department of astronomy is the David Dunlap Observatory in Richmond Hill, Ontario. The main telescope is a 74 inch (1.88m) reflector — the second largest telescope in the world when it was opened in 1935, and still the largest optical telescope in Canada. On top of the administration building at the observatory are three smaller telescopes (24 inch, 19 inch, and 6 inch).

The University of Toronto operates a 24 inch telescope in the Chilean Andes near Las Campanas. As well as providing Canadian astronomers with a chance to observe the southern sky, its position at about 7,000 feet altitude offers one of the best and driest observing sites in the world. The astronomy department is also currently involved in construction of the Canada-France-Hawaii 141 inch (3.6m) telescope which is now being assembled on Mauna Kea in Hawaii.

Radio astronomers at the University of Toronto maintain a 60 foot radio telescope at the Algonquin Radio Observatory, which is operated by the National Research Council of Canada.

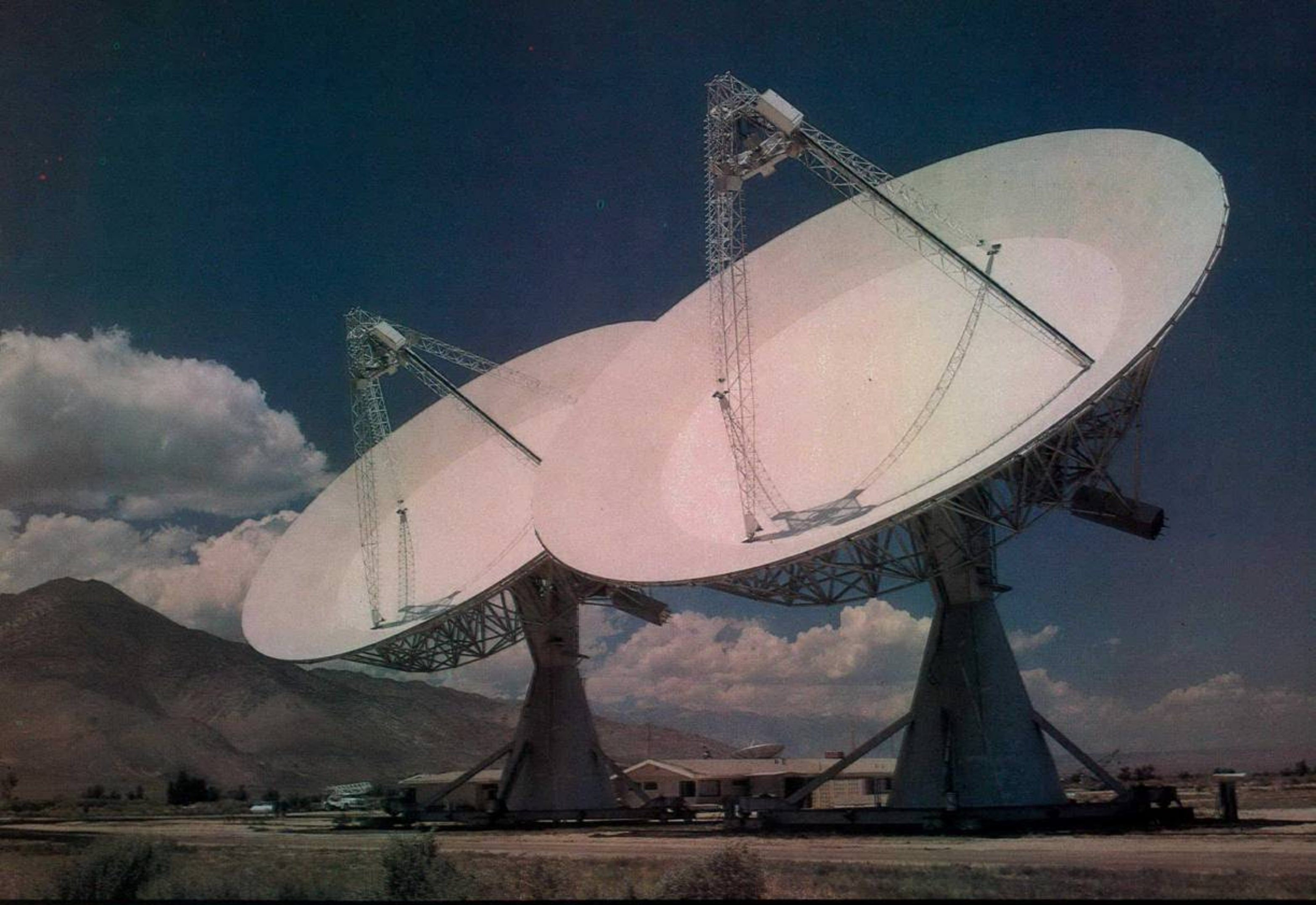
Theoretical research joins with all modes of observational research in studying such diverse problems as cosmology and the internal constitution of stars. Some of the areas being studied by staff and graduate students are the structure and evolution of galaxies and star clusters, black holes and double stars, the physical and chemical nature of stars and the way they change with time, and the interstellar medium out of which perhaps our sun and we were formed.

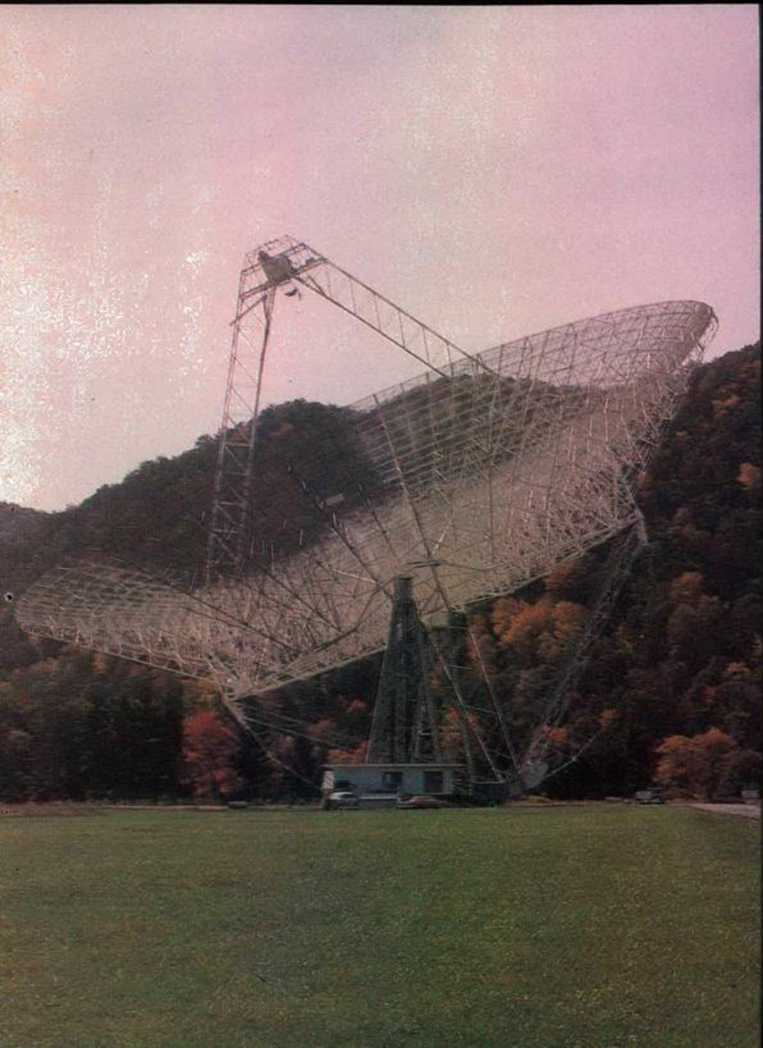
in a dry location may suddenly double when infrared and optical astronomers combine to put it into round-the-clock service.

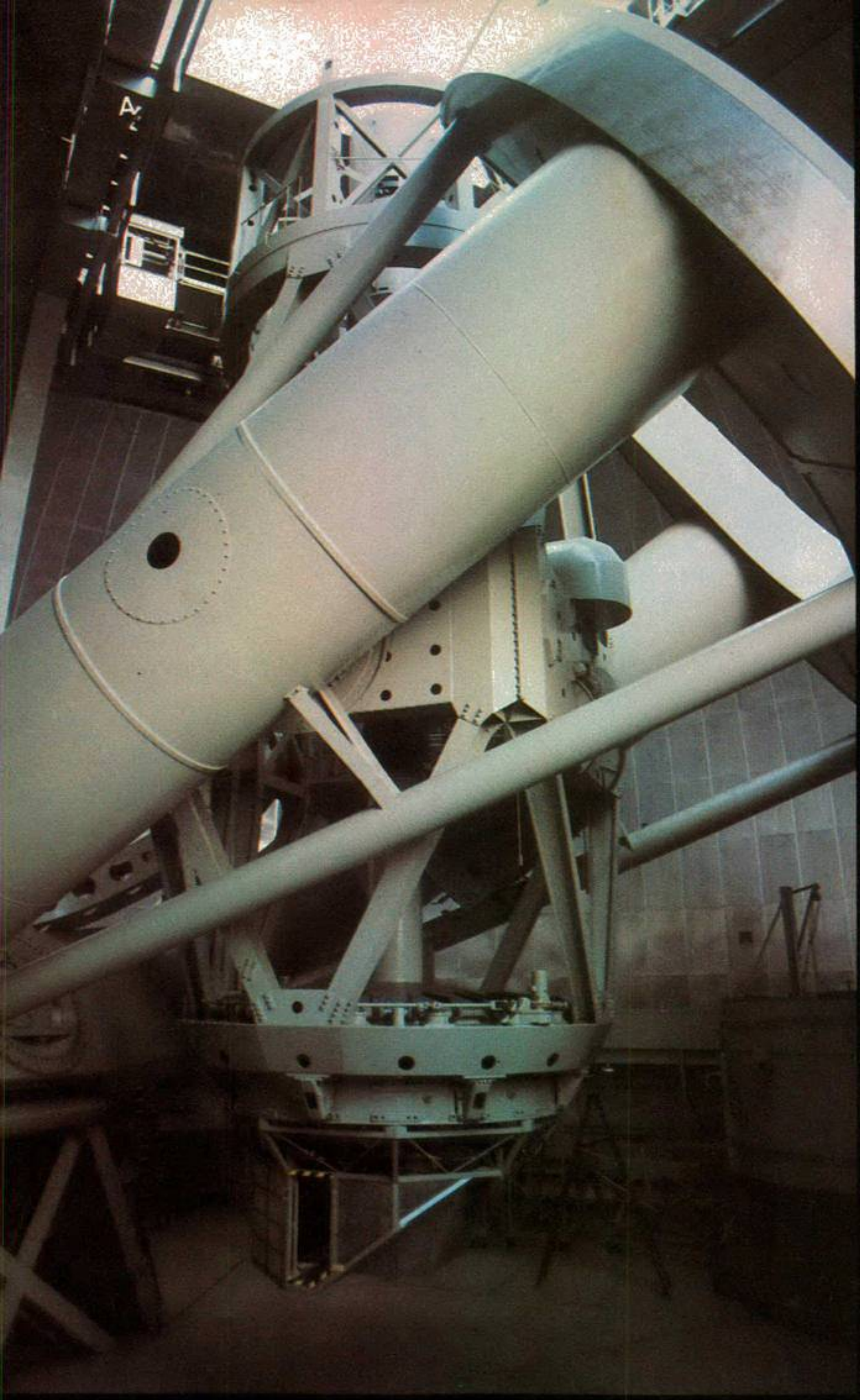
Mountains, especially along some margins of continents, combine these advantages. High altitude, clear skies, extreme dryness, and good seeing are found in the American southwest and California, in the Chilean Andes, on Hawaiian volcanic peaks, the Canary Islands, the coast of Spain, parts of the east coast of Australia, and in Southwest Africa. Remote sites create difficult construction problems, complex logistics, additional expense, political problems, and travel time. But it's worth it. The world's newest telescopes promise to be the most productive instruments ever built — and that, in no small part, is because of their excellent sites.

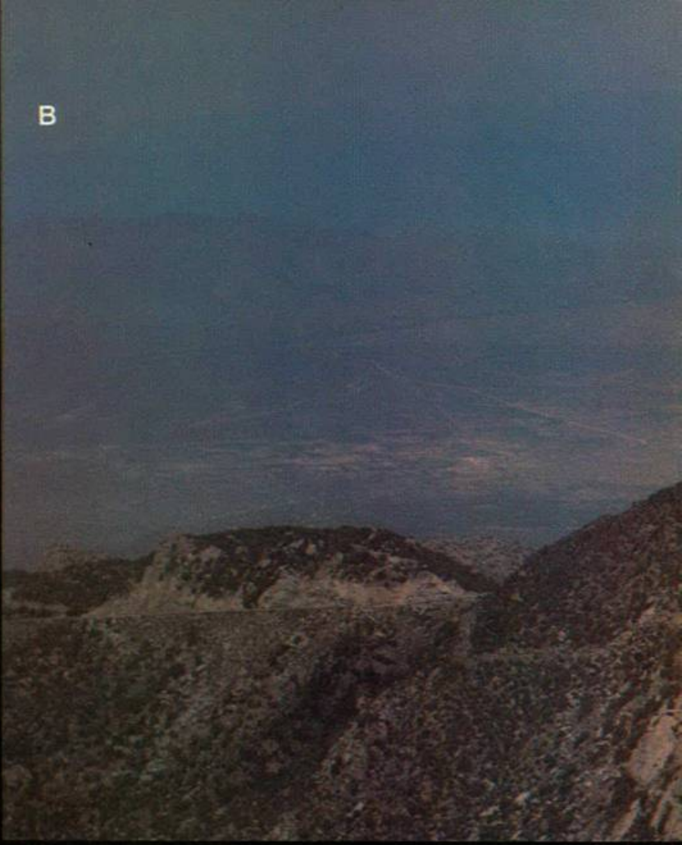
During the 1980s, a new telescope will be placed in the ultimate observing site: space. The Space Telescope will be launched aboard the Space Shuttle, carefully set up and checked out by astronauts, and then left to function via radio links to astronomers on the ground. In space, all limitations imposed by Earth's atmosphere will be gone. Seeing will be perfect, the sky dark, clouds nonexistent, and there'll be no water vapor. At the command of the astronomers who control it, instruments on board the Space Telescope will take the best pictures of galaxies ever, record spectra previously impossible to reach, measure infrared radiation with new precision, and obtain ultraprecise stellar positions.

Opposite, top: Radio astronomy has become fundamental to modern astronomy. Located in the Owens Valley (Calif.), and shielded by mountains from manmade radio interference, are these dishes of a large radio interferometer. Left: The National Radio Astronomy Observatory (NRAO) is America's national radio facility. Located in Deer Creek Valley at Green Bank, W.V., it is isolated from manmade radio signals. The largest dish is seen here: It is 300 feet (91 meters) across, and can listen to radio signals from a great variety of sources such as exploding galaxies and pulsars. Center right: At night, the Australian "dish" in Parkes is brightly illuminated. Another picture of this radio telescope is on pages 6 and 7. Photographs by Jay Pasachoff. Lower right: The 22 meter radio telescope of the Crimean Astrophysical Observatory in Simeis, Crimea, USSR, has been used in cooperation with NRAO radio telescopes in Very Long Baseline interferometer observations that provide extraordinarily high resolution on objects such as quasars. Photograph by David Shaffer.

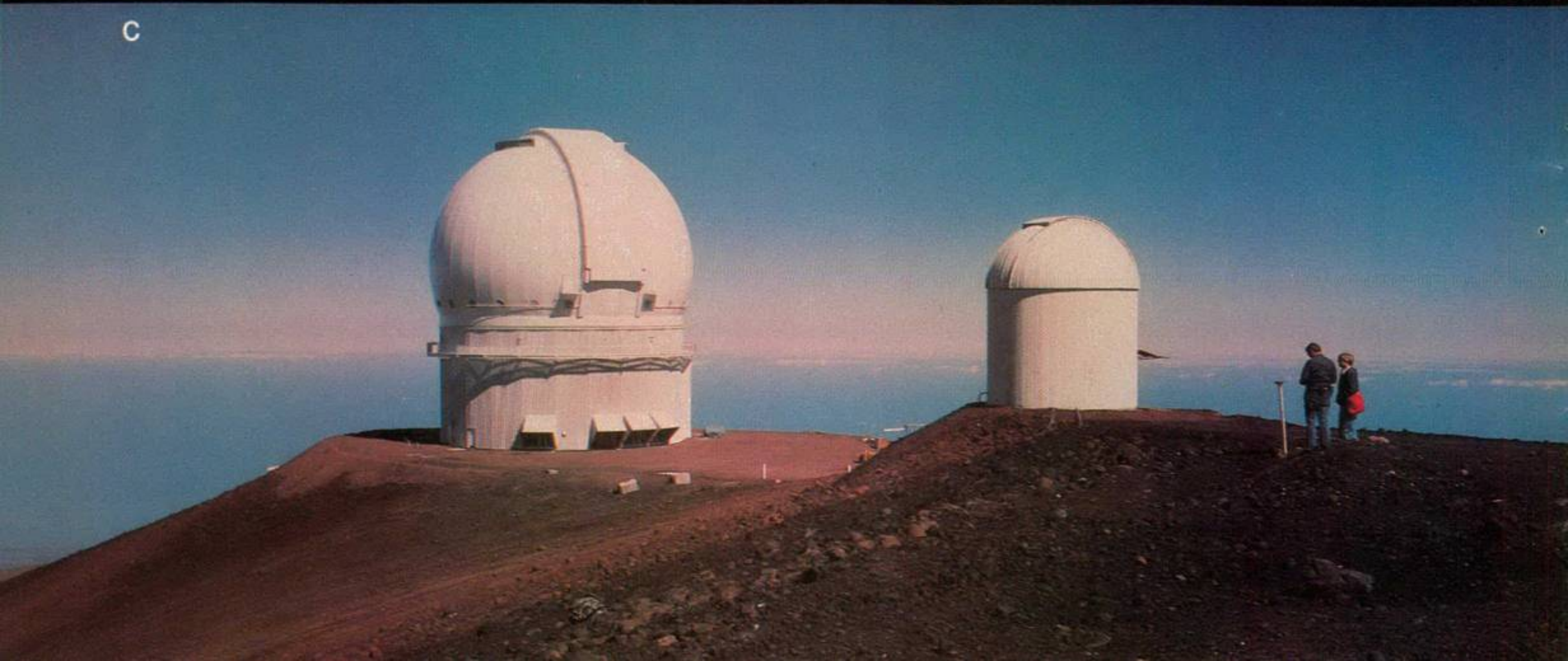


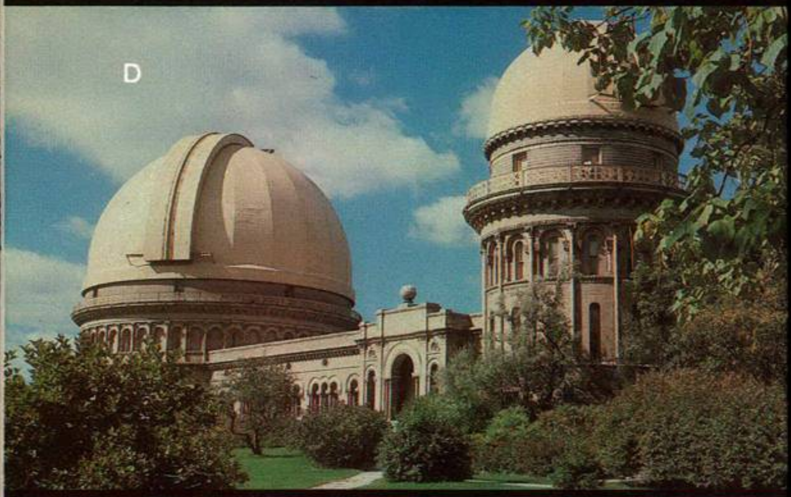






The world's observatories are often located in high, dry, remote places where astronomers can use their instruments to full capacity. The 200 inch (5 meter) Hale telescope (A) is located atop Palomar Mountain in southern California. Photograph by Jay Pasachoff. Kitt Peak (B) has one of the greatest concentrations of large telescopes in the world. The biggest dome houses the 158 inch (4 meter) Mayall telescope. Photograph by David Shaffer. On the dry peak of Mauna Kea (C) are the 88 inch (2.2 meter) University of Hawaii telescope and the dome for the 141 inch (3.6 meter) Canada-France-Hawaii telescope. Photograph by Janet Lesh. Yerkes Observatory (D) houses the 40 inch (1 meter) refractor — the world's largest. Photograph by Janet Lesh. Kitt Peak is silhouetted against the brightening morning sky, as tired and hungry astronomers finish their night's work (E). Photograph by David Lewis. Observatoire du Pic du Midi (F) in France has long been known for its exceptionally good seeing. Photograph by Jay Pasachoff.





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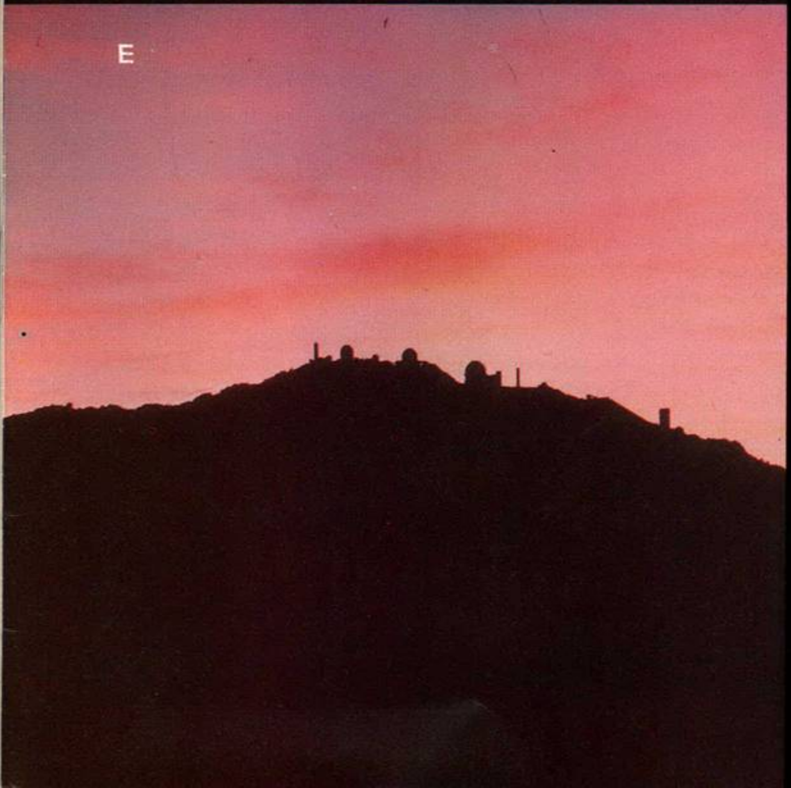

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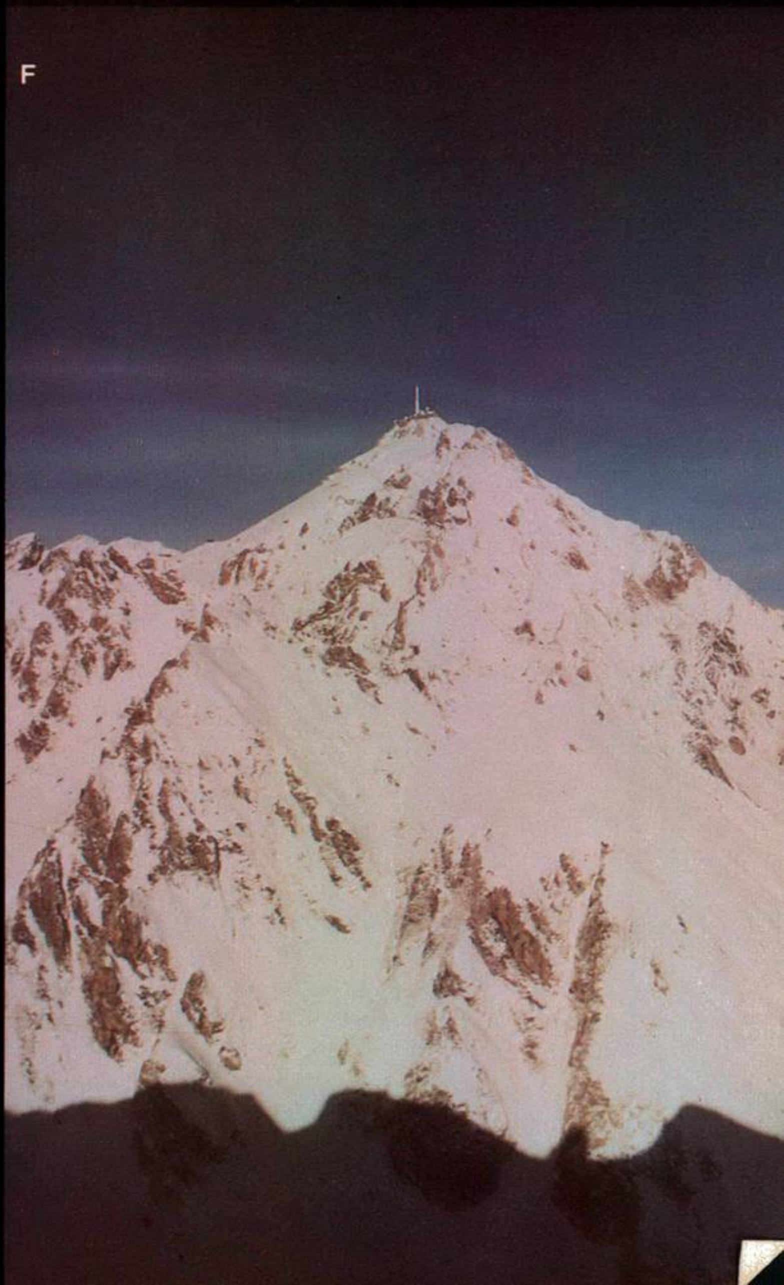


F

Giant Optical Telescopes

6.0m	236"	Specsialnaja Astrofizicheschakaja Observatorija, USSR
5.0m	200"	Hale Telescope; Palomar Mountain, California, US
4.0m	158"	Cerro Tololo Inter-American Observatory, Chile
4.0m	158"	Mayall Telescope; Kitt Peak National Observatory, Arizona, US
3.9m	153"	Anglo-Australian Telescope; Siding Spring, Australia
3.6m	142"	European Southern Observatory, Chile
3.6m	141"	Canada-France-Hawaii Telescope, Mauna Kea, Hawaii, US
3.5m	140"	Osservatorio Astronomico Nazionale, Italy
3.0m	120"	C. Donald Shane Telescope; Lick Observatory, California, US
2.7m	107"	McDonald Observatory, Texas, US
2.6m	102"	Byurakan Observatory, USSR
2.6m	102"	Crimean Observatory, USSR
2.5m	100"	Hooker Telescope; Mt. Wilson Observatory, Hale Observatories, US
2.5m	100"	Irénée du Pont Telescope; Hale-Carnegie Institution, Chile
2.5m	98"	Isaac Newton Telescope; Royal Greenwich Observatory, UK
2.4m	94"	Space Telescope, to be launched in the 1980s
2.3m	90"	Steward Observatory, Arizona, US
2.2m	88"	University of Hawaii, Mauna Kea, Hawaii, US
2.2m	88"	Max Planck Institute, Calar Alto Mountain, Spain, Germany
2.2m	88"	Max Planck Institute, SW Africa, Germany
2.15m	84"	Kitt Peak National Observatory, US
2.15m	84"	La Plata Observatory, Argentina
2.1m	82"	Otto Struve Telescope; McDonald Observatory, Texas, US
MMT Six 1.8m mirrors functioning as one 4.4m mirror, Mt. Hopkins Observatory, Arizona, US		

New Telescopes

There's been a revolution in the telescopes themselves, too. Of the four optical telescope projects in the world having the greatest light gathering power, two are radical departures from classic designs, and could not have preceded fast computers. The telescopes are the Russian 236 inch (6 meter) reflector, the American 200 inch (5 meter) reflector, the Multiple Mirror Telescope (MMT) of Hopkins Observatory — soon to become operational — of doubly radical design, and the Cerro Tololo 158 inch (4 meter) telescope in Chile.

The Russian instrument is not mounted on an equatorial mounting, and cannot track the stars with a simple one speed motor driving it. Its mounting is altazimuth, and it tracks with two motors that must run at continually changing speeds controlled by a computer! The altazimuth design costs about half as much as a conventional equatorial mounting, and its simple mechanical design opens the door to still larger telescopes.

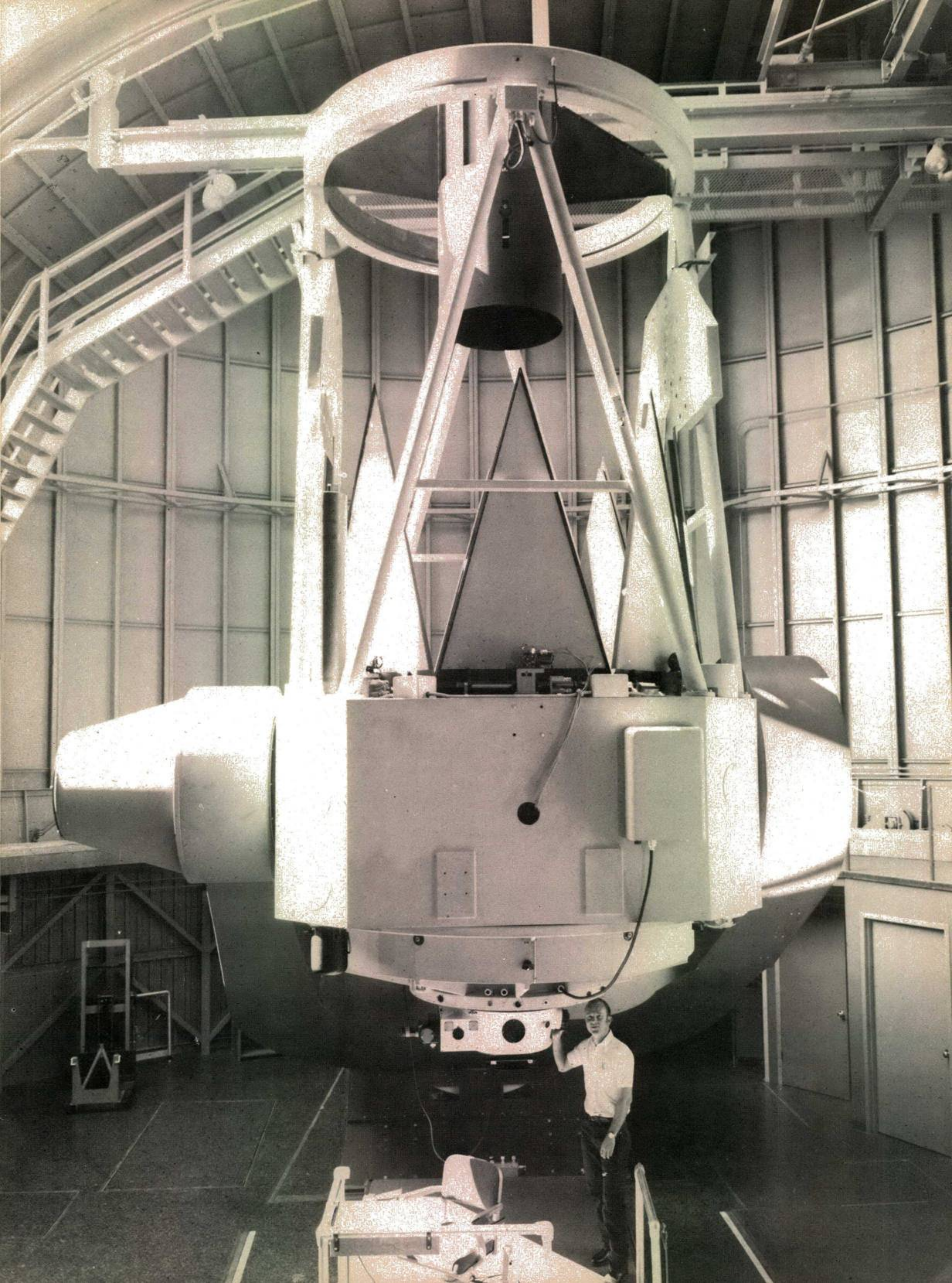
The Multiple Mirror Telescope is a new concept. Instead of a single large mirror, it uses six 72 inch (1.8 meter) mirrors to focus light into astronomers' instruments — *and* it is mounted on an altazimuth mounting controlled by a computer. The concept of an observatory dome has also been taken a step further with the MMT. The dome is a compact, efficient square structure that turns with the telescope, carrying observing laboratories, control room, electronics room, darkrooms, and observers along with it!

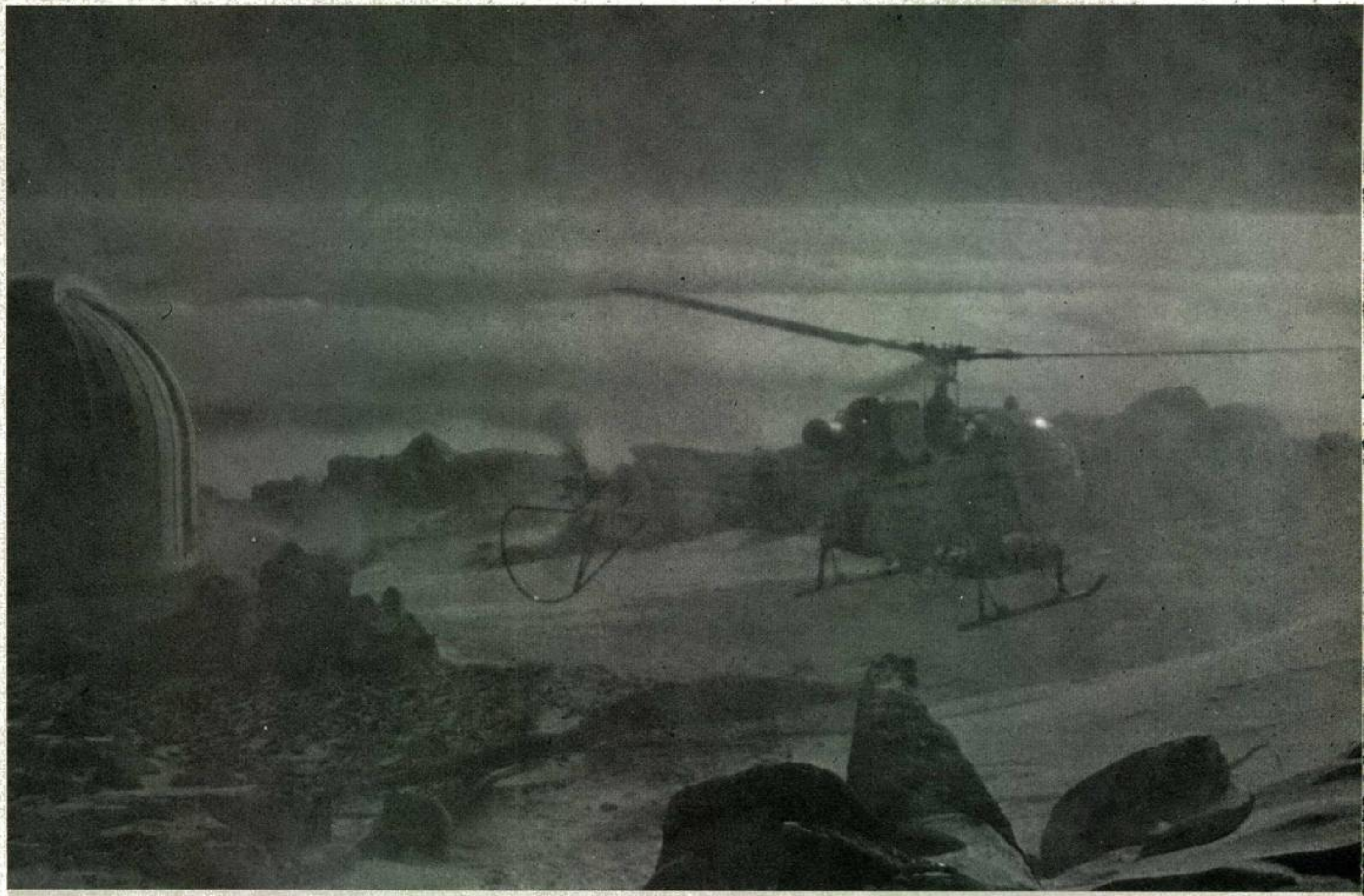
Besides the testing of radically new designs, the last decade has seen an explosion of new telescope projects — most becoming operational within the last few (or the next few) years. Only 10 years ago, the Palomar 200 inch (5 meter), the Lick 120 inch (3 meter), and the Mount Wilson 100 inch (2.5 meter) — three aging giants — were the world's biggest. Today there are 11 new, completely modern telescopes larger than 100 inches . Of those new instruments, four are in the southern hemisphere, exploring an important part of the sky that was previously inaccessible to the world's major observatories. The new telescopes are better than the old ones, and most employ efficient wide angle optical systems at prime focus that let the new generation telescopes complete photography programs faster. At Cassegrain focus, under the superb skies in the Chilean Andes, some of the new instruments regularly photograph stars far fainter than the 200 inch telescope could reach.

Behind the better telescopes are better observing instruments and techniques. Breakthroughs in understanding photographic processes brought "Instamatic" film to photobugs, and more efficient plates to astronomers. The best fine grain, high efficiency emulsions record stars a magnitude fainter than could be reached a decade ago. Image intensifier tubes give exposure time gains of 10 to 100 times — again allowing work that was impossible a decade ago. Sensitive television cameras, experimental then, are today's shelf items. TV systems allow an astronomer to get *off* the telescope, high above the floor in the cold, and into a warm room,

REVOLUTION *continued on page 18*

The Steward Observatory 90 inch (2.3 meter) reflector was one of the first telescopes built on Kitt Peak. This instrument, like most large telescopes, is frequently used as a Cassegrain. Light from a star strikes the primary mirror at the bottom of the tube, is reflected back to the secondary mirror near the top, then back down through a hole in the primary mirror to cameras, spectrographs or photometers located on the tailplate. University of Arizona photograph.





AN ASTRONOMER'S LIFE IS NEVER DULL

by

Janet Rountree Lesh

When I was a child growing up in Evanston, Ill., I would go to the public nights at Northwestern University's Dearborn Observatory to look through the 18 inch refractor. Two objects that I saw were especially memorable: the planet Saturn looking like a ball of yarn with a knitting needle stuck through it (the rings were then viewed almost edge-on), and a pea green star with a purple halo called Vega. Never having heard of chromatic aberration (a property of lenses, which causes light of different colors to focus in different places), I retained the image of that pea green star throughout high school and into college at Cornell University, where I took the astronomy course to find out more about this mysterious object. It was disappointing to learn that although stars can be blue or yellow or red, there is no place for a green star in the sequence. Vega, in particular, is as white as any star can be! But by that time I was hooked, and I went on to later get a Ph.D in astronomy from the University of Chicago, having meanwhile spent several years in France as a Fulbright Fellow in astrophysics.

Most people think astronomers spend all their time looking through a telescope. Actually, it has been many years since an astronomer really *looked* through a telescope for any purpose other than to focus or center the image, or to show a celestial object to a visitor. As a light detector, the human eye has long since been replaced by photographic plates and, more recently, by television tubes and photon-counting devices. Then, too, the amount of time actually spent at the telescope collecting data is small in comparison with the time required to *analyze* the data. But telescopes still play an essential part in modern astronomy, and it's been my privilege to work with some instruments which — while not among the world's largest — are among the most idiosyncratic.

Take the University of Denver's Mt. Evans Observatory, for example. At an altitude of 14,100 feet, it is the highest, permanent, ground based astronomical observatory in the world. Tourists swarm over the mountain in the summer, but at other times of year it is abandoned to the mountain goats, badgers and conies, the hardier of the local alpinists — and the astronomers.

The main advantage of extreme altitudes is the lack of water vapor in the atmosphere, making it more transparent to the infrared radiation that our bodies perceive as "heat waves". So Mt. Evans is designed as an infrared observatory, with a conventional 24 inch reflecting telescope. A variety of devices that can "see" long wavelength radiation can be mounted on it. But infrared detectors are fussy; they work best at temperatures near absolute zero. Liquid nitrogen and liquid helium to cool them, as well as water and food for the human observers, must be trucked in over often tortuous roads — or ferried in by helicopter when the roads are completely closed.

A typical observing day begins in early afternoon (no waiting until dark to see if it will be clear!) with a trip from the base station at 10,000 feet (itself a beautiful colony of log cabins set in a piny wood) to the summit, to check out the equipment and cool the detector. Calibration measurements begin around sunset, with observations of the moon and any available planets. These measurements are repeated throughout the night, alternating with measurements of the target infrared source — a star, nebula or galaxy. Since the Mt. Evans telescope is relatively small, observation times for typical infrared sources are long, and the telescope points at only a few positions during the night. Keeping warm — or even just staying awake — during these comparatively long periods of inactivity can be a problem. But later, after a long period of analysis, the observations will yield new information on the cool material around and between the stars, and in the outer layers of planetary atmospheres.

Performing a spectroscopic or photometric survey is quite a different type of observing. If the project includes a sample of stars spread over the entire sky — to study their distribution in the galaxy, for example — it may require a half year or more of actual nights at the telescope. Exposure times are usually short, and the aim is to cover as many stars as possible in one night, so the telescope is frequently swept from place to place on the sky. With some telescopes, this can be an impressive procedure: Seeing the 60 foot long, 20 ton bulk of Yerkes Observatory's 40 inch refractor swing ponderously around its pier is almost as awe inspiring as looking at the stars themselves. Although it is at a much lower elevation than Mt. Evans, Yerkes often has more severe winters. With the aid of a night assistant, I was once well on my way to setting an observatory record for observing at -25 degrees Fahrenheit. Then the dome began to rotate and refused to stop until the main power was cut off. Deciding that the machinery was trying to tell us something, we closed up for the night!

Darkroom procedure is as important as telescope time in spectral classification work, and many observational astronomers become photographers out of necessity. Uniformity of development requires that the temperature of the developer be controlled to within one degree Fahrenheit. Unless the darkroom has some pretty sophisticated equipment, this means dabbling your fingers in the developer to keep it warm in winter, and floating the tray in ice water in the summer. It's a good way to get dishpan hands — but it produces good spectra!

Another of my favorite places for spectroscopic observing is the Haute Provence Observatory, near the town of St. Michel l'Observatoire in southern France. Amid the lavendar covered foothills of the Alps, astronomical observations blend smoothly with the joys of French cuisine and the opportunity to visit nearby relics of ancient and medieval civilizations. For although St. Michel is not far from such major tourist centers as Avignon and Arles, it is more original and somehow more poignant to spend your afternoons (between morning's sleep and night's observing) looking for half-forgotten remnants of the past — Roman columns standing forlornly in a farmer's field, the half-buried door of a ruined abbey, primitive dwellings or watch-posts called bories, whose origin is as remote as Stonehenge. Haute Provence has a number of good telescopes, including the modern 76 inch (193cm) and 60 inch (150cm) coude reflectors, but my best friend there is the old 48 inch (120cm) instrument. Its Newtonian focus puts you really close to the stars as you observe!

This year, while continuing some research on infrared astronomy, I am concentrating on the other end of the spectrum — the ultraviolet radiation from stars, which has to be observed from satellites because ultraviolet is absorbed by the terrestrial ozone layer. Observing with a satellite means, of course, that you don't see the telescope at all. But the dividends are great. For example, some variable stars whose light changes by only about 0.01 magnitude in the visible wavelength region vary by 0.1 magnitude in the ultraviolet, and can be much more easily detected in this way.

This, then, is what it's like to be an astronomer: To view the stars with many instruments and from many places — trying to learn as much as possible about how they work, but always keeping in mind the beauty that inspired you to look at them in the first place.

Sacramento Peak Observatory

Many stars like the sun have sunspot cycles. One of the main tasks of solar physics is to try to develop a convincing theory for the way in which the sun, and stars like it, generate magnetic fields that erupt as sunspots during the 22 year solar cycle. The sun somehow behaves like an electrical dynamo; it converts organized motion, such as rotation and large size convection, into strong currents and magnetic fields. At Sacramento Peak, solar astronomers are studying all aspects of the mechanisms by which this happens. This involves making very precise measurements of both velocity and magnetic fields for long periods (several years), analyzing the results very carefully, and comparing them with existing theories and refining these theories.

Sacramento Peak is perhaps the largest and best equipped observatory devoted exclusively to studying the sun in the world. It has a large variety of telescopes, but the two most important are the Vacuum Tower Telescope and the 16 inch (40cm) Coronagraph. The Vacuum Tower Telescope produces a 20 inch (50cm) diameter solar image. Details on the sun as small as 1/4 second of arc — a mere 110 miles (180km) — are occasionally detected with this very fine instrument. The Tower has several powerful instruments to study the sun's spectrum, with photographic or photoelectric recording, and a narrow band filter that can be tuned over the entire visible spectrum to produce nearly monochromatic pictures of the sun.

The 40cm Coronagraph is used primarily for studies of the solar corona, the hot outer atmosphere of the sun. In effect, this instrument can make an artificial eclipse any day of the year. With additional solar equipment the coronagraph can be used to measure magnetic fields on the surface of the sun.

Sacramento Peak Observatory plays two roles. First it offers the best scientific equipment for the use of solar observers in this country and abroad. Secondly, the observatory staff is investigating a number of solar problems that have applications for stellar astrophysics and geophysics.

We can only see the surface of the sun or its extended atmosphere, but not its interior. However, new techniques are being developed — at Sacramento Peak and elsewhere — to explore the deep interior of the sun. These involve searching for pulsations of the entire sun. If they exist at all, the pulsations must have a very small amplitude — about 6 miles (10km) — as compared to the several hundred thousand kilometer radius of the sun. The character of the pulsations are predicted to depend upon the internal structure of the sun, so that if the pulsations can be detected and studied, solar astronomers can learn about the interior in the same way geophysicists learn about Earth's interior from earthquakes.

Another large area of interest concerns the heating of the outer atmosphere. The corona has a temperature of about 2,000,000 degrees, compared with a surface temperature of only 6,000 degrees Kelvin. The belief among solar astronomers is that the atmosphere is heated by sound waves that are generated just below the surface, propagate upward and form shock waves. Thus, sound energy is converted into heat. Although all sorts of motions — including oscillations and streaming — have been observed in the solar atmosphere, there is as yet no real evidence for these progressive sound waves or shocks. An alternative is that the magnetic field plays some role in heating the atmosphere, either by guiding sound waves or dissipating electrical currents. Strenuous efforts are underway at Sacramento Peak to test these ideas.

During the flight of Skylab, the corona was photographed in x-rays over a period of nine months. These photos showed that the corona is missing in certain regions that are now called *coronal holes*. We now know that coronal holes are the sources of high speed streams in the solar wind: The gas is missing in holes mainly because it is streaming into space so rapidly. The high speed streams shake Earth's magnetic field when they sweep by, causing great disruption of radio communication. In addition, there is slight evidence that the fast wind streams and their associated magnetic fields may influence Earth's upper atmosphere in some way, and conceivably modify the long-term climate of our planet. Thus there is a great deal of interest among astronomers and geophysicists in understanding how the streams originate, how they propagate through interplanetary space, and how they might interact with Earth's atmosphere. At Sacramento Peak, astronomers can observe coronal holes daily and predict at least a week in advance when the disturbance will arrive at Earth. This is only a first step in studying how the streams originate in the corona and how the whole process varies throughout the solar cycle.

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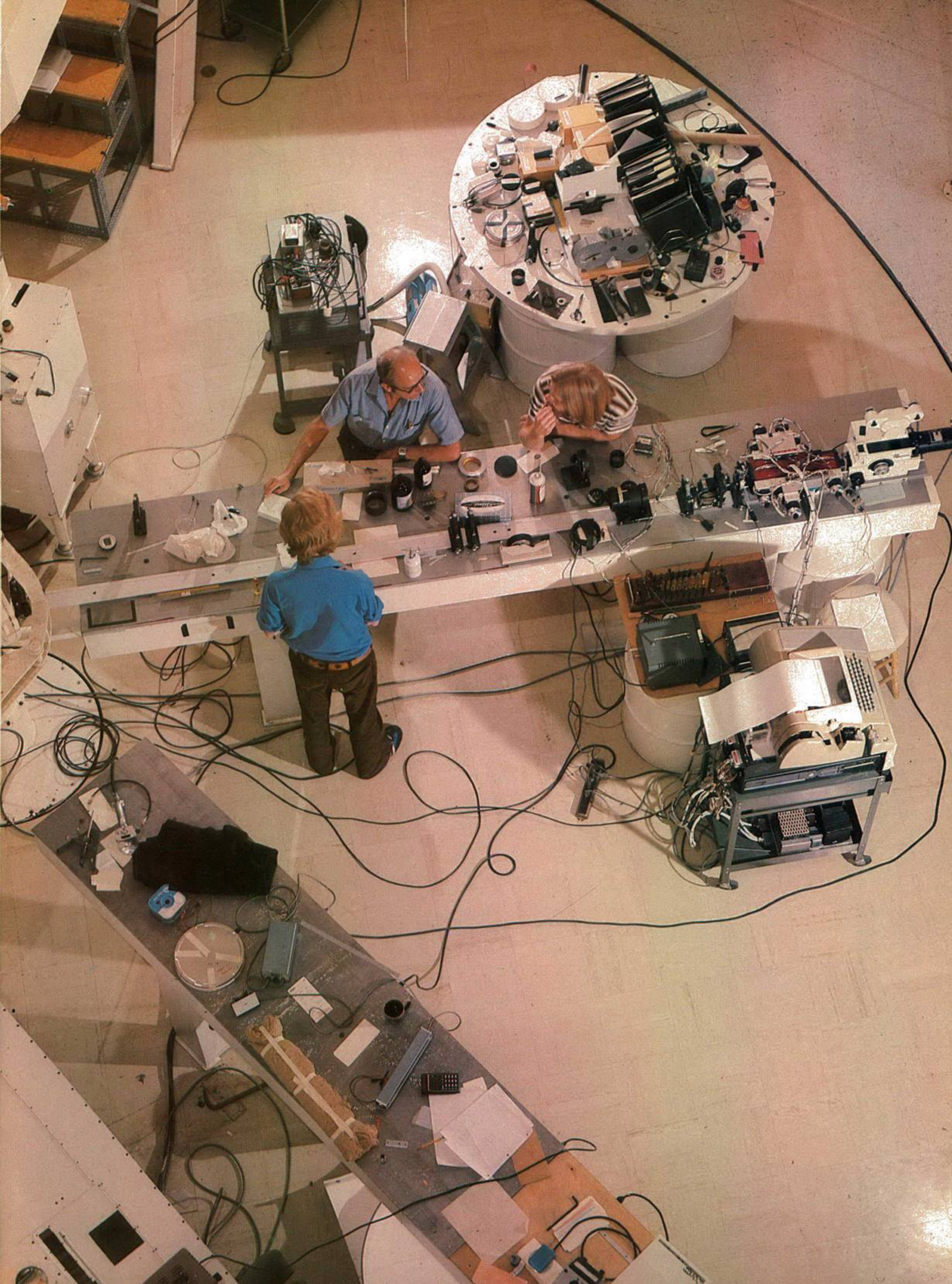
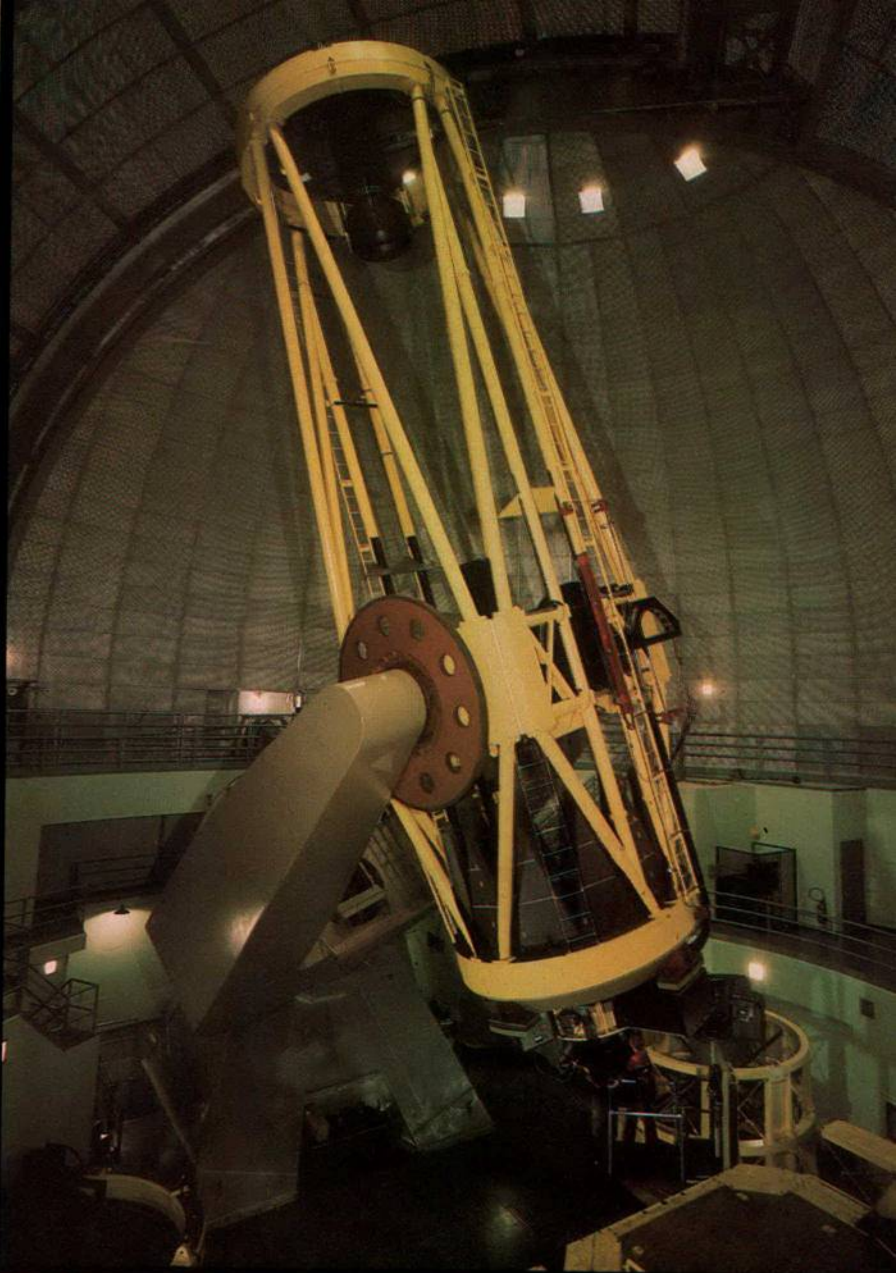
while being able to locate and study fainter stars on the TV screen than he could by looking directly through the telescope.

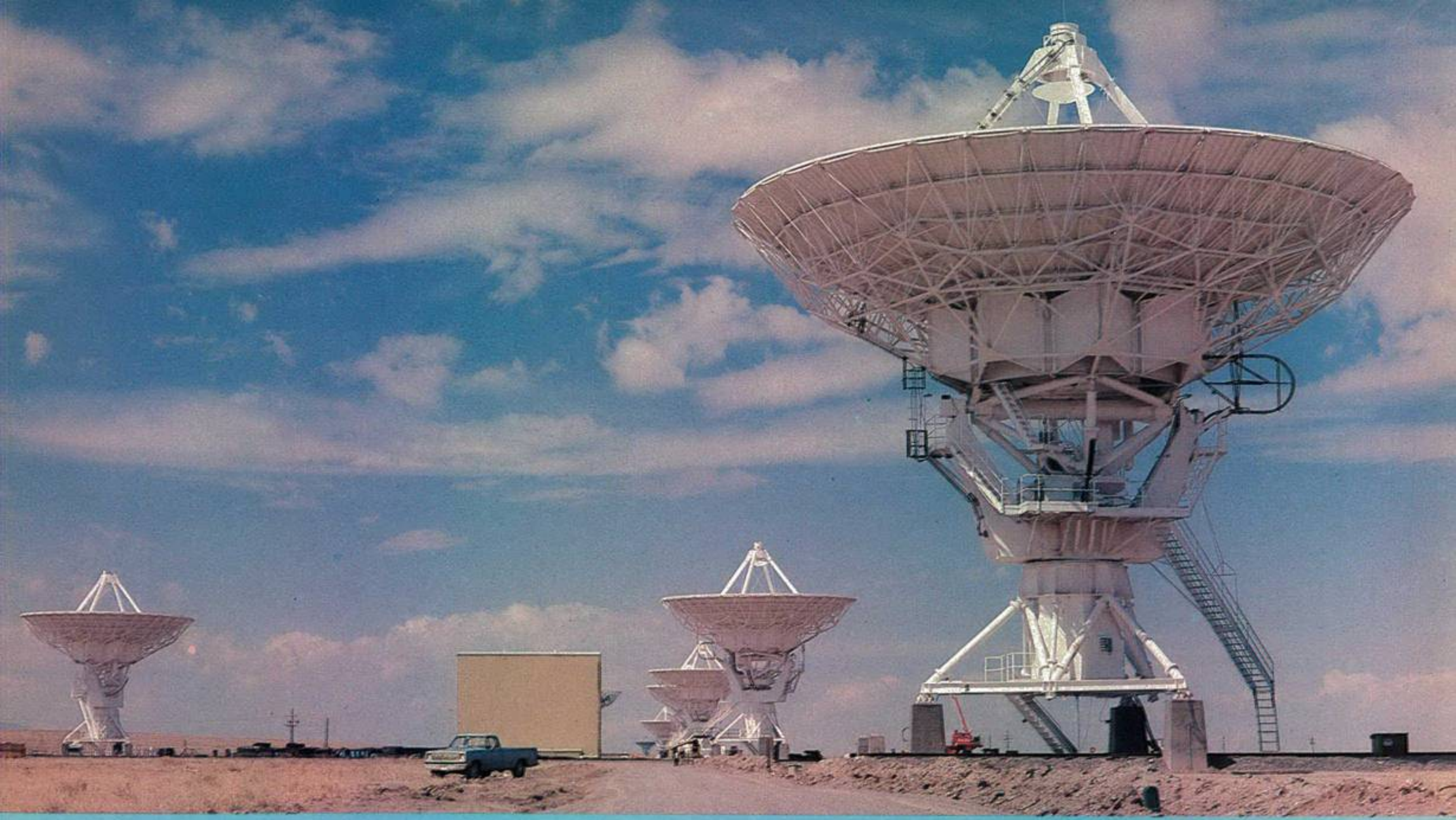
Backing the better instruments are better methods of analysis. Especially in photography, but also with many electronic sensors, getting all the recorded information back out of the detector isn't always easy. Film scanning machines are now used routinely to extract all the accurate numerical data recorded on pictures taken with the big telescopes. After computer processing and enhancing the images, details and brightness variations that were there (but not easily visible) are brought forth and quantified. Automatic position measuring machines are another important development. For positional astronomy, stars recorded on a photographic plate must be measured with very high accuracy; as little as 0.001 millimeters (1 micron) or 1/25,000 inch can make a difference. A machine called GALAXY, developed at the Royal Observatory in Scotland, measures the brightness and positions of all the stars on a photographic plate; later, pairs of plates can be compared by computer to find unusual, interesting stars.

Observers at the Sacramento Peak Observatory Vacuum Solar Tower discuss the setup of the Lockheed Solar Filter for visiting scientists from Lockheed Solar Observatory. The filter is the small red box located near the end of the optical bench. The entire observing platform and telescope — weighing some 250 tons — rotates while tracking the sun. The solar image can be directed in five different directions for different experiments. Sacramento Peak Observatory photograph.





Left: Attached to the massive "tail" of Lick Observatory's 120 inch (3 meter) C. Donald Shane telescope is the most heavily used auxiliary instrument: the Image Tube-Image Dissector Scanner (ITIDS), essentially a device for obtaining the spectra of stars. While observing, the astronomer rides a movable platform. Here, Dr. Sandra Faber is shown changing filters in the instrument. Lick Observatory photograph. Above: The Starscan Automatic Measuring Engine is used to obtain ultra-accurate star positions from photographic plates made to determine the distances to stars. U.S. Naval Observatory photograph. Right: The Shane reflector, seen from below on the opposite page, is the major research instrument at Lick Observatory. Bottom: An astronomer can control any instrument mounted at the Cassegrain focus of the Shane telescope from this control room. The television system in the upper left is used for guiding the telescope; the computer and CRT terminal are used to gather and display data from the ITIDS. Lick Observatory photographs.



Photograph by Gerrit Verschuur

The World's Largest Radio Telescope

by
Raymond R. Gibson

The world's largest radio telescope, the Very Large Array (VLA), is under construction near Magdalena, N.M. Construction of the 27 radio antennas which comprise the telescope was begun in 1971 by the Association of Universities for Research in Astronomy, Inc., under contract for the National Radio Astronomy Observatory. The instrument is scheduled for completion in 1981.

The VLA will extend over portions of six ranches in the plain of San Augustin. The antennas will be moved outward to permanent foundations by diesel-hydraulic transporters. Nine antennas will be placed along each of three "arms" at a spacing selected to maximize the instruments ability to receive radio signals. The radio signals will be amplified at the antennas and transmitted to the control center by 60 millimeter waveguides entrenched along each arm. The radio signals will be digitized and stored in vast digital libraries for analysis by radio astronomers.

Since two or more antennas can simulate a single antenna of a large diameter, the VLA, with its 27 movable antennas, will be a very powerful instrument indeed.

Where could such a field of antennas be placed? After considerable study, the San Augustin Plain was selected for the site. The plain is an almost ideal location for the instrument; it's a vast lake bed remaining from the more humid climates of the last glaciation periods. The lack of radio interference was a major reason for selection of the site, and the broad, level area is ideal for easy movement of the antennas.

Construction of the VLA began in 1973. A central site was prepared for construction of the control center for the instrument. Utility systems, parking areas, maintenance facilities and access roadways were under construction in the late fall, and work continued until late 1976. A master control laboratory and cafeteria have been constructed at the central site. Construction is well along on the railroad track (for transporting the antennas) and also on the permanent foundations for the antennas. Observations were begun in early 1976; in 1977, these observations were used to check calibration procedures for the antennas. In 1981, the telescope will go into full operation as the world's largest radio telescope.

The VLA will also be used by scientists visiting from throughout the world. These scientists will reserve time, and with the help of the permanent staff of the VLA will make their observations. The staff will assist in setting up the array to make the proper observations. The configuration of the antennas will be changed for different wavelengths and resolution requirements. The 225 ton antennas will be moved from one permanent foundation to another as required by the transporter, which will travel about five m.p.h. under ideal conditions along the double track railroad connecting all the permanent foundations.

Four principal arrays are provided for in the construction plans. Several foundations on each arm serve in more than one array, and 72 permanent foundations will allow positioning of the 27 antennas in all arrays. The antennas may be bunched in a group — all within 1/2 mile of each other — or they may be extended to the largest array, covering a circle almost 20 miles in diameter.

In contrast to many of the scientific installations in New Mexico which are defense oriented, visitors are welcome at the VLA. The site is readily accessible from U.S. 60, and is 25 miles west of Magdalena.

McDonald Observatory

McDonald Observatory's history begins in 1926, when a wealthy west Texas banker died, leaving the bulk of his estate in the hands of the University of Texas regents. A self-taught amateur scientist, W.J. McDonald had a passion for stargazing and a desire that his fortune be used to "aid in erecting and equipping an astronomical observatory for the promotion and study of the science of astronomy".

The McDonald money was not enough, however, to both build and operate a major observatory. Fortunately, Otto Struve of the Yerkes Observatory was looking at the time for an observatory site in the southwest, to escape unfavorable weather conditions farther north. The University of Texas and the University of Chicago thus joined forces in building McDonald Observatory, and the two schools operated it jointly for 30 years. By 1962, the astronomy department at UT had grown large enough to take over sole responsibility for the observatory's operation.

McDonald Observatory is located 450 miles west of Austin, in the sparsely settled Davis Mountains. The mountain on which the observatory now stands is named Mount Locke, in honor of Violet Locke McIvor, who donated it along with 200 acres of surrounding land. The site is in an extremely isolated area, where the nights are most often clear, inky black, and bright with stars.

The 82 inch telescope — now officially called the Otto Struve Reflector — was the first telescope on Mount Locke. When it was dedicated on May 5, 1939, it was the second largest telescope in the world.

Today there are four optical telescopes at McDonald — all reflectors. In addition to the 82 inch, there is a 30 inch (1970); a 36 inch (1956), and a 107 inch (1965-69). The 107 inch telescope, with its large coude spectrograph, was built as a jointly funded project between Texas and NASA to be used — among other things — for long-term studies of the solar system. Two major solar system activities have developed so far: the lunar laser ranging program, and the planetary program.

Lunar laser ranging has been conducted at McDonald for the past eight years (since the summer of the first manned moon landing). This program utilizes the telescope as both a transmitter and a receiver for a high powered laser beam shot toward retroreflector panels on the moon's surface. Three times daily, for three weeks each month, the laser beams pass out through the telescope, hit the lunar panels and bounce back. When reflected photons are detected, their flight time is measured within an accuracy of one billionth second. That time measurement establishes the momentary distance between Earth and the moon. Such measurements have improved our knowledge of the moon's orbit, which in turn has served to test different theories of gravity.

Both the 107 inch and 82 inch telescopes are used to make regular spectroscopic studies of each planet and each large moon in the solar system. Besides gathering data of general astronomical interest, the planetary program provides information about the planets' surfaces, atmospheres and weather conditions that is valuable to NASA in designing space probes, flybys and soft landers. Important information toward the successful Viking landings was provided by McDonald's planetary research team.

Beyond the solar system, some main areas of observation research are:

1) Chemical abundances in evolved stars — it was recently discovered that the star Betelgeuse has an encircling shell 400 times larger than the orbit of Pluto.

2) High speed photometry of cataclysmic variables — a recent discovery is of white dwarf stars that pulsate with periods as short as 11 seconds.

3) The structure and evolution of galaxies — including work on a major revision of the distance scale of galaxies, and on the evidence for clustering of galaxies into superclusters.

4) Optical identification of extragalactic radio sources — with subsequent redshift and astrophysical analysis, mainly using data from the UTRAO radio sky survey (see below).

5) Pulsating variable stars — a new discovery is of "tidal waves", analogous to tidal waves on Earth, that move around on the surfaces of young stars.

6) Fundamental determination of stellar masses and radii — including a systematic program of determining the radii of stars occulted by the moon.

Theoretical studies done by the University of Texas astronomy department include work on star formation, theoretical models of quasars, and neutron stars and black holes in binary systems.

Two radio telescopes are affiliated with McDonald. A millimeter wave telescope located on Mount Locke is operated jointly by McDonald and the University of Texas electrical engineering department. This 16 foot, gold plated dish antenna is one of the few telescopes of its kind in the world. Funded by NASA and the National Science Foundation, astronomers from McDonald and elsewhere in the country use the antenna to detect radio waves from organic molecules in interstellar gas clouds. The molecules are a key to understanding conditions inside the clouds, where new stars are thought to be forming.

The University of Texas also operates the Radio Astronomy Observatory (UTRAO) located near Marfa, Tex., 40 air-miles south of McDonald. Researchers there employ the Two-Mile Telescope, a radio interferometer consisting of a number of straight line arrays of antennas partially covering four square miles of ground. The Two-Mile Telescope is effectively a radio Schmidt, looking simultaneously at 120 different positions in the sky. Its principal use at present is in detecting signals from extragalactic radio sources, including quasars and radio galaxies. Precise coordinates for these sources are now being obtained in a four-year sky survey that will result in the radio counterpart of the famous Palomar sky survey.

Of course, the flood of data from electronic sensors would overwhelm an astronomer who insisted on doing his data reduction entirely by hand. Computers are there to do the drudgework, freeing astronomers to work with astronomical results rather than tedious computation.

New Ideas, Theories

Astronomers work long observing runs in chilly domes and spend long hours reading scientific journals in order to remain "current" in their

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THERE'S MORE TO ASTRONOMY THAN OBSERVING

by

Nancy D. Morrison

I've been strongly interested in astronomy since I was about 15, when I read Fred Hoyle's book **Frontiers of Astronomy**. His discussion of stellar evolution fascinated me, and gaining an observational understanding of that process is still my main research interest. I majored in astronomy in college, and finally obtained my Ph.D in 1975 from the University of Hawaii.

The photograph on page 25 shows me as a Ph.D student, tending the spectrograph at the Cassegrain focus of the 2.2 meter (88 inch) telescope on Mauna Kea (13,800 feet altitude). My heavy clothing shows that an astronomer sometimes has to cope with a rigorous environment. For me, though, the cold is relatively unimportant when I can look up along the telescope through the slit in the dome at a brilliantly starry sky.

Observing is important to an astronomer, but it accounts for only a small portion of his or her time. In the last two years, I've spent 140 nights observing — only 1/5 the total number — but this is still much more than most astronomers can claim. Most of the time, astronomers work with stars — not as things that can be directly sensed, but as blackened grains on a photograph, wiggly lines on a strip chart recording, numbers punched on computer cards, or points on a graph. I spend most days measuring positions or densities on a photographic plate, manipulating numbers with a computer, reading technical papers (if I can find the time), talking with colleagues, and writing. Though much of the data reduction work is routine, I am never at it for long without coming to a point at which a decision is necessary. A description of the decisions that I (and many of my colleagues) face in the course of carrying out a research project may convey something of what it is like to work as an astronomer.

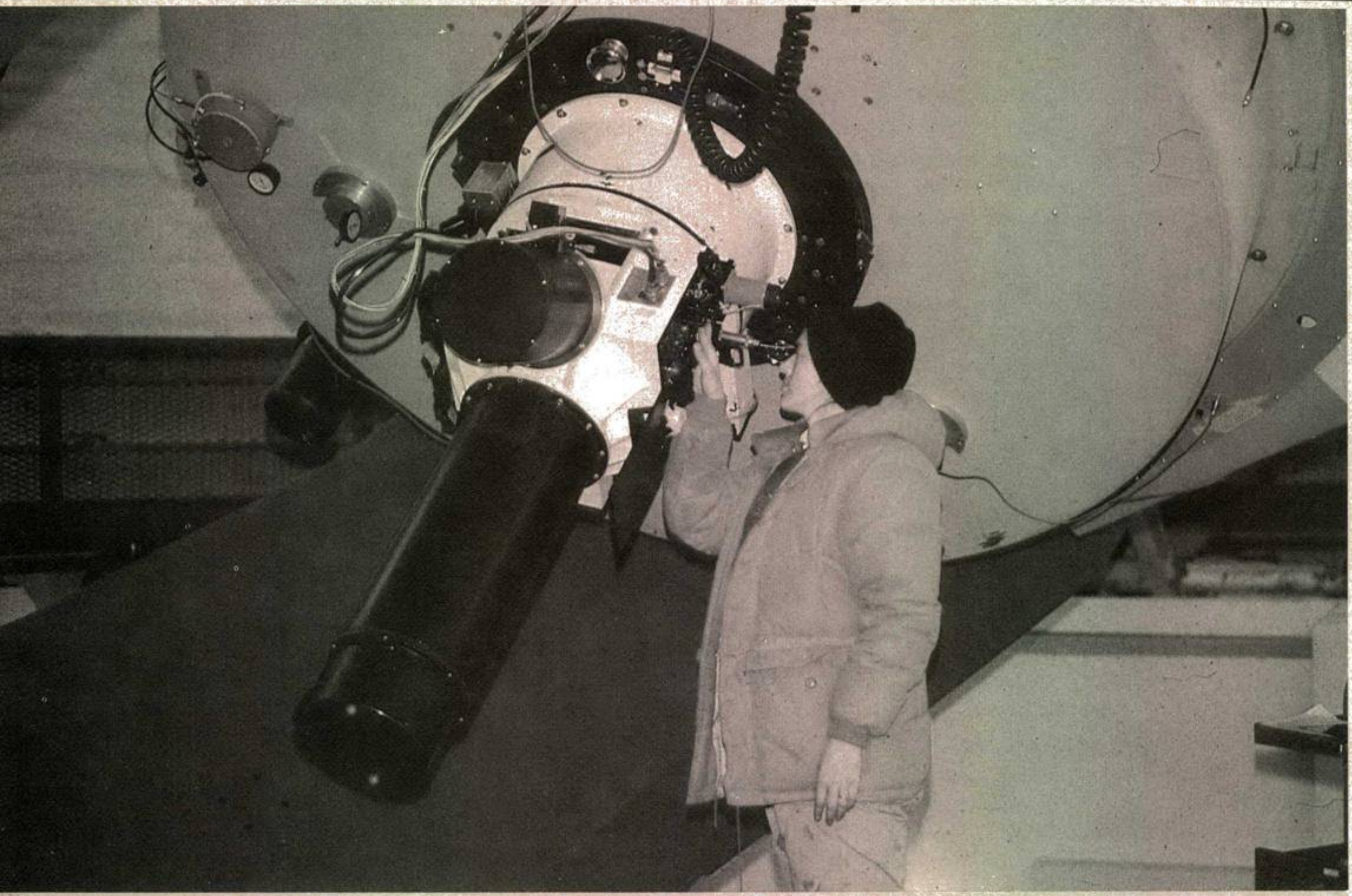
Important decisions have to do with conclusions (if any) that can be drawn from data that contain, in addition to the information you are seeking, *noise*. One kind of noise is that due to the graininess in a photographic emulsion. In astronomy, where low light levels often mean a weak "signal", uncertainties due to noise are often major.

In the study of binary stars, one of the basic observational materials is a *spectrogram* — a photograph of a star in which the light has been spread out so that each wavelength falls at a different place on the photographic plate. At certain characteristic wavelengths, at which the abundant atoms in the stellar atmosphere prefer to absorb light, there is less light than at other wavelengths. Such features are called *absorption lines*. Now, if there are two similar stars in a binary system so close together that they appear as one in the telescope, they will be orbiting about each other. Most of the time the two stars will have different velocities; therefore, their absorption lines will appear at different wavelengths, and the lines on my photographic plate will appear double. In the type of stars I'm studying, the absorption lines tend to be indistinct, and their shapes are apt to be distorted by the graininess of the emulsion. So I may find myself at the measuring machine with a spectrogram of a suspected binary star, preparing to measure the positions of the lines but unable to decide whether they are single or double. I postpone the necessity for a decision by measuring the lines both as single and double!

Clearly, if a large percentage of my spectrograms of a star are such that I can't tell whether the lines are double or single, my prospects for learning much about the star or pair of stars are poor. I can only comfort myself with the thought that, if the system were an easy one to analyze, someone would already have analyzed it.

To show that a star is a binary if the lines are single, it's necessary to show that its velocity varies periodically as it would have to in an orbit. So, the first step in determining the orbit is to find the period. Techniques exist for finding the period by computer from a long series of observations, and *in principle* these techniques can be applied without much thought. *In practice*, because of noise in the data, or because the data don't span a long enough time, the computer routines can yield the wrong period. Many astronomers, including myself, have at one time or another reported an erroneous period in print! Before you can be confident of the period, you have to check *all* reasonable alternatives.

After careful checking, it may turn out that only one period comes close to being consistent with all the data, and therefore it's probably the correct one. What do I conclude, then, if I have data from one binary orbit, for example, that are discordant with other data — indicating a different trend? Does the binary system have a component, such as a gas stream, that doesn't behave the same way on every orbit? Since such an inference would be very important, it's vital to examine the evidence carefully. Something may be wrong with the data: perhaps an optical misalignment of the spectrograph or a numerical error in the reduction. If no problem is evident, I can check whether the discrepancy is really larger than the observational uncertainties. Judging what these uncertainties are can be difficult. Ultimately I may find several



reasons to revise upward my estimate of the inaccuracies, so it becomes greater than the discrepancy I have found — at which point the discrepancy becomes insignificant!

On the other hand, if I still have a real discrepancy, I have two choices. One is to omit the discrepant data and take the risk that I may be overlooking something important. If I do draw attention to the effect, one of two unpleasant consequences may follow. My result may be valid but impossible to interpret, particularly if it never recurs. Or it could be wrong, and another astronomer will have to expend great effort to prove it wrong, wasting valuable time.

Finally comes the most important activity of all: deciding what the results mean. For example, consider a problem that a colleague and I are attacking piecemeal, even though we are years away from its solution. Suppose that, out of a sample of 20 very rapidly rotating O type stars, I were to find that 12 were binaries. Since I couldn't show that the others were *not* binaries, I would ask whether all such stars are binaries. A statistical test would answer that question, probably equivocally. If the answer is yes, I can conclude that membership in a binary system somehow leads to rapid rotation — at least in these cases. To determine how the members of the binary influence each other in this fashion, I would try to learn (perhaps by making more observations) what distinguishes these binaries from other binaries that contain O type stars but don't have rapid rotation. I might find, for example, that the rapidly rotating stars are young systems that have never undergone evolution and mass exchange, while the slow rotators usually have undergone these changes. I would then have learned something about how members of a binary system interact with each other as they form and evolve. Afterward I might try to interest a theoretically minded colleague in trying to develop a theory on the formation of massive binary stars. Before this process advanced too far, I would make sure that I wrote up the early results for publication.

On winter evenings, I sometimes leave the office with my head buzzing with questions like these. As I come to a dark part of town I stop, if the sky is clear, to look at Orion as it rises. Many of its bright stars are of the kind I work on (the three stars in the belt, for example). I've spent many hours observing the easternmost and the westernmost of those three. It's exhilarating to think that these objects I study make up one of our most beautiful sights.

Nancy D. Morrison holds a postdoctoral position at the Joint Institute for Laboratory Astrophysics at the University of Colorado at Boulder. In her research, she uses photometric and spectroscopic observations to determine the masses of very hot, luminous (O type) stars in binary systems.

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fields. They churn through endless reams of computer output or photographic plates from the last observing run. They discuss, discuss, and discuss again their work with their colleagues, always looking for the insight that will spell meaning for a pile of numerical data. They battle through fruitless hours of checking when nothing seems to make sense, and finally draft, rewrite, and submit a scientific paper — which can be turned down if the work is not up to par. In addition, most astronomers carry teaching responsibilities which take them away from research, cramming already full schedules to the limit. And for the most part they enjoy it — because it's the work they really want to do.

The "name of the game" in astronomy — indeed in all sciences — is rigorous precision in thinking. Even the most farflung speculation must fit the overall picture, contradict no established "facts", and satisfy the rules of scientific etiquette. To an outsider, science seems repressive and staid. To those working in it — those who accept the most basic rule, "You have to be able to back up everything you say" — it's a fast, challenging intellectual game. Every scientific statement is tentative, contingent, and qualified by an implied body of assumptions — in a society where most statements are absolute, definitive and authoritative.

Radical revisions in astronomy's "big picture" in the last few decades show that scientific rigor is not closed to new ideas. In the 1950s, the universe was a quiet, rather static place. Galaxies looked like peaceful collections of stars, and the whole universe seemed consistent with a *steady state* cosmology. Astronomers occasionally discussed discordant facts and examined unusual objects that didn't fit the picture, but most of the work in astronomy was going into understanding the stars, establishing more data about distances to galaxies, and filling in the unknown areas left in the *island universe* theory (accepted in the 1920s).

Then, when radio astronomy provided lists of radio sources, optical astronomers eagerly tried to identify their optical counterparts. They soon discovered what was, in some cases, a new type of object, apparently very distant, receding from us at immense speeds, and having incredibly high energy output. *Quasars*, as they came to be called, triggered a theoretical revolution. They stimulated a far reaching search for new, powerful sources of the energy needed to drive them. Old facts were reexamined; theories long regarded as uncheckable were checked against the new objects. The *big bang* theory gained favor among astronomers. The discovery of pulsating radio sources (called *pulsars*) led to striking confirmation of old theoretical predictions of neutron stars, paving the way toward widespread acceptance of, and searches for, observational evidence for black holes. Satellites and rockets above the atmosphere brought further confirmation of new data. That violent events occur commonly, that gravitational potential energy probably powers quasars, and that the universe began in a cosmic fireball 20 billion years ago — these theories are now the order of the day. But their full acceptance is contingent on further confirmation, qualified by the accuracy that the new theories can continue to agree with new observations. Astronomers will not change their minds on a whim, nor will they support a theory that doesn't work. The debate, the challenging of old assumptions, the re-evaluation of evidence — that's the part that's fun!

More About Observatories . . .

Observatories are serious research laboratories. In general, unexpected visitors are unwelcome, but most have visitors' hours and daily or weekly tours. For the best compilation on when to visit and what you'll see, consult H.T. Kirby-Smith's book, **U.S. Observatories: A Directory and Travel Guide**.

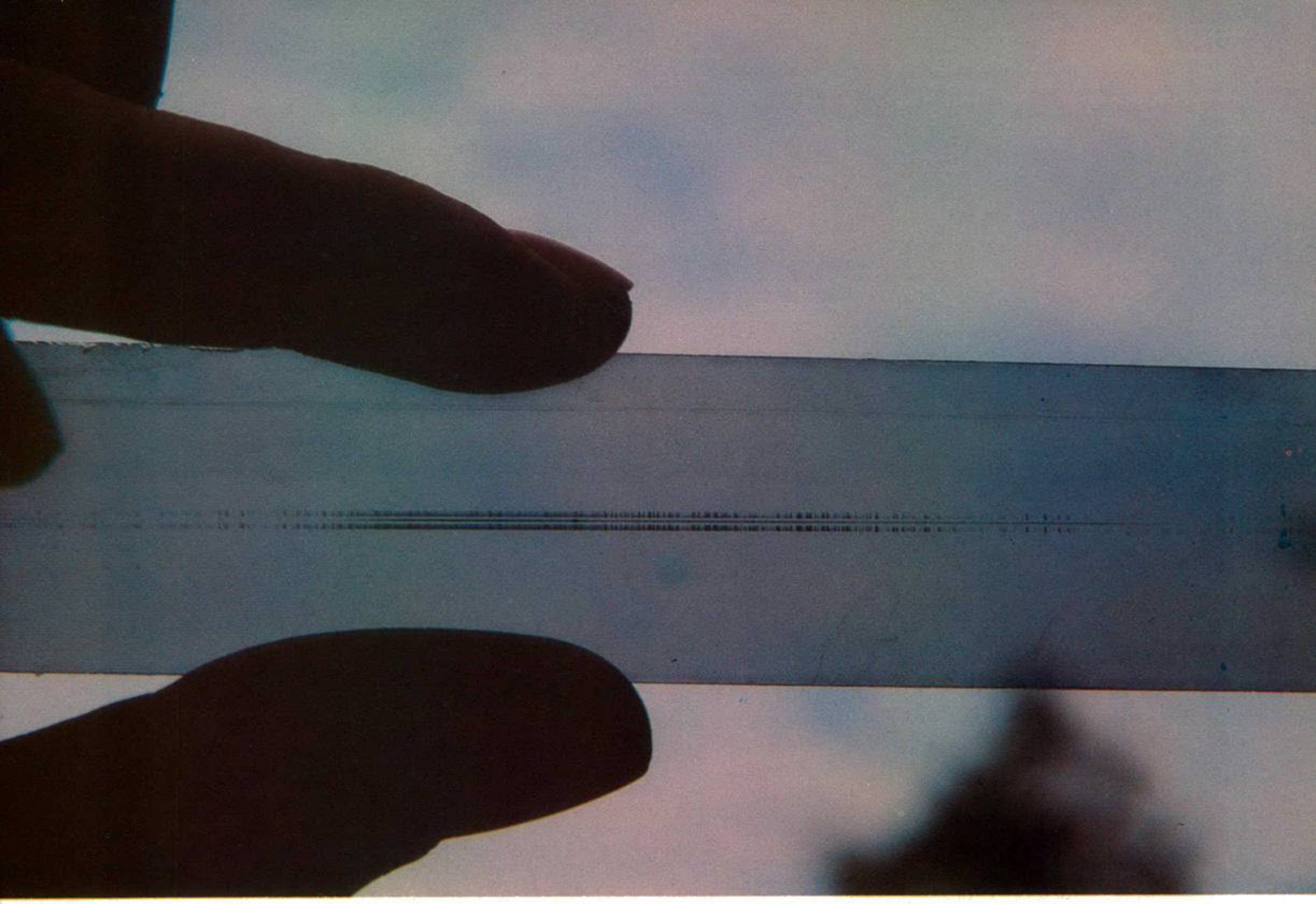
The Basic Units

Astronomy can be divided into two different areas: *astrometry*, which deals with the positions and motions of the stars, and *astrophysics*, which deals with the brightness, temperatures and physical conditions of the stars and space. Astrometry is the less glamorous field, but it's the source of much of the fundamental information that astrophysicists require. In the last few years, radio astrometry has become feasible with multi-antenna radio telescopes. Measuring the positions and separations of radio sources promises to be an exciting field because it is a direct probe into the energetic cores and gas clouds of quasars and radio galaxies.

Astrophysics is the other side of astronomy — the big telescope side, the glamorous side. Astrophysics deals with temperatures, pressures, big exciting concepts and "whiz-bang" results about what stars and galaxies are really made of and how they got that way. Astrophysicists working in all parts of the spectrum, including the visible region that human eyes can see, use four basic techniques in all their work: image recording, spectroscopy, photometry and polarimetry.

Spectroscopy is the real core of astrophysics. An object's spectrum tells much about it. From the characteristic spectral lines of atoms, we find familiar elements in the most distant quasars. Astrophysicists can tell the temperature, pressure and motion of an object toward or away from us — all from its spectrum.

Behind the four basic techniques of astrophysics is another field called *laboratory astrophysics*. Though astronomers cannot reach out to



When an observing run is over, the astronomer may return to his university post, taking with him a small box of photographic plates, a few rolls of magnetic tape, a pile of chart paper, or a sheaf of print-out. The real work then begins. Here is a spectrum plate of the variable star R Corona Borealis made with one of the giant spectrographs of the 200 inch (five meter) Hale telescope. Photograph by Jay M. Pasachoff.

touch stars, alter and manipulate a nebula, or run a controlled experiment with a supernova explosion, they can learn as much as possible about how atoms behave here on Earth. Astronomy and astrophysics have provided much of the impetus for physicists to understand atoms, how they're constructed, and how they react under extreme physical conditions.

The Infinite Universe

When you step outside at night to look up at the glittering stars, do you ever stop to think of the thousands of other people on the night hemisphere of Earth who are probably also looking up with you? Do you ever think of the far smaller number of men and women whose lives are spent trying to understand the heavens, how the stars shine as they do, why the galaxies have spiraling arms, and when the universe came into being? Over several generations, absorbed students of the sky, working at isolated observatories and living strange night-oriented lives — a small group of specialized scientists — have revolutionized our concepts of the universe again and again and again. Our concepts of the universe have progressed from a flat Earth to a round Earth, to an Earth circling the sun instead of being central, to the sun being one star among many, to the stars being part of a great star system called the galaxy, and to finding that our galaxy is just one among many, all fleeing a great primordial explosion. Astronomical history is a story of one amazing revelation following another, and astronomers have totally altered the way humans perceive the celestial sky.

Astronomy today, like most sciences, has progressed beyond easy comprehension. The radiation astronomers receive from the planets, stars and distant galaxies extends beyond human ability to sense directly. Infrared, ultraviolet, x-ray, gamma ray, radio and millimeter wave — all important to the progress of modern astronomy — are abstractions to most people and probably always will be. Distances, sizes, temperatures, pressures, densities, masses — the conditions in space, in stars, on distant worlds — these things are perhaps too alien for humans to embrace directly. But indirectly, through your imagination, you can experience the universe of the modern astronomer. With all instruments recording, with computers computing, through graphs and charts, diagrams and printouts, with care and precision in thinking and theorizing, astronomers have created a vision of a universe unequaled in the history of human thought.

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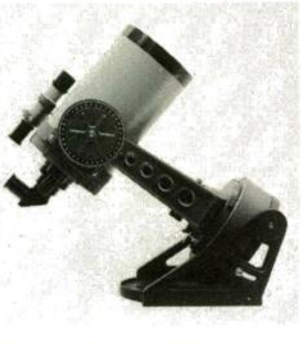

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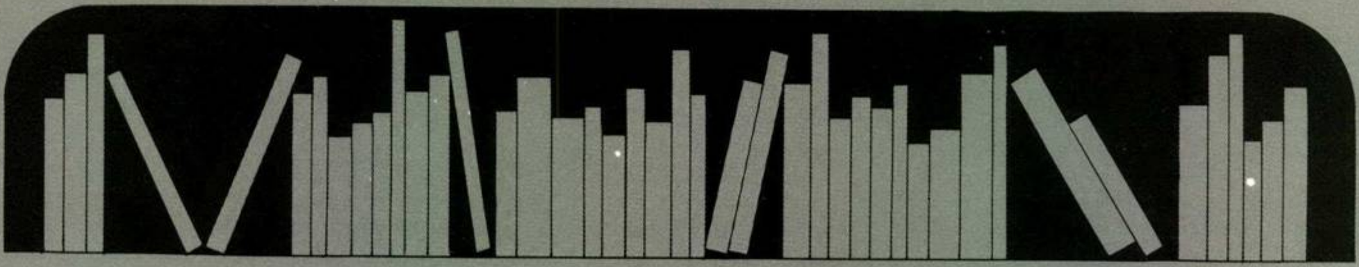

ASTRONOMY REVIEWS

Astronomy for the Amateur

by JOHN GRIBBIN

93 pages (illus.), hardcover, $5.25
Macmillan London Ltd. (1976)

If a little knowledge is a dangerous thing, then a small book which attempts to introduce the reader to amateur astronomy in its entirety is at best superficial and at worst unforgiveably misleading. **Astronomy for the Amateur** is such a book.

In eight short chapters, Gribbin tells us about constellations and naked eye observations, the selection and use of telescopes, observing everything from the moon to distant galaxies, celestial photography, and even radio astronomy! His treatment of these subjects is not only brief but also filled with questionable statements, puzzling inconsistencies, and even several embarrassing printing errors.

In the first chapter, Gribbin suggests that because very few of the constellations really resemble the mythological creatures they supposedly represent, it is not worth trying to recognize them at all! "How can we ever expect to locate any particular star our of the 3,000 or so visible to the naked eye!", he asks. "The answer is simple. Ignore most of the constellations altogether." All you really have to be able to recognize are three prominent patterns, he explains — Orion, Cassiopeia, and the Plough (the Big Dipper). Everything else will soon be located "quite painlessly" in relation to these three.

What nonsense! Certainly Cygnus does not really look like a swan; Leo is a lion only to those with considerable imagination, and Auriga in no way resembles a charioteer. But they *do* contain stars which form very prominent and easily remembered patterns in the sky, and one of the most enjoyable pastimes for a beginner is learning to discover these. The author is correct in saying it is almost impossible to see the great bear as a bear — but how puzzling that he uses that fact as an excuse for ignoring the many obvious star patterns that clearly exist within most of the constellations!

On the subject of selecting a telescope, Gribbin again makes some questionable statements. Because all the largest telescopes in the world are reflectors, he refers to purchasing a small refractor as a "completely misguided" act: ". . . in practical terms any astronomer who wants to progress to a large instrument must end up with a reflector — so why not start out with one?", he asks. He also contends that no telescope should be regarded as portable and that a six inch reflector (or, if you insist, a three inch refractor) is "the smallest worth having". Gribbin is certainly entitled to his opinion, but once again his logic is puzzling. Very few beginners will ever desire to progress to a really large instrument, and as a small telescope the refractor certainly has several distinct advantages. A closed tube, almost carefree maintenance, and easy portability are points that should not be overlooked. The fact that most professional astronomers work with reflectors is quite irrelevant to astronomy enthusiasts, and since so many of us live in and around cities where the seeing is poor, a small portable refractor might turn out to be an excellent choice.

Other curious statements, and a few obvious blunders, occur throughout the book. In the chapter entitled "Beyond the Solar System", for example, the Crab nebula — hardly one of the best objects in a small telescope — is put in the same class with the Orion nebula and Andromeda galaxy as "the other nebula to which any newcomer to astronomy must soon turn his telescope." In the section dealing with astrophotography, deep sky photography is discussed as if it were a relatively easy trial and error process. No mention is made of accurately aligned equatorial mounts, carefully adjusted clock drives, or extra equipment such as guidescopes and slow motion controls. And in some ways worst of all, the two most impressive color photos included near the middle of the book are both printed incorrectly as the mirror images of their actual appearance in the sky! (Ironically, one of these is of Orion, one of Gribbin's three acceptable constellations!)

The most disappointing aspect of Gribbin's book, however, is the glaring inconsistency between the introduction and the viewpoints expressed in later chapters. In the introduction, the author talks about the "sense of wonder which can make the study of the world about us so exciting" — a sense of wonder which may be lost to many "scientists" but which perhaps still lives in the minds of "ordinary people". Yet later as his emphasis swings toward *useful* observations, he too sounds like the scientists, and little mention is made of wonder anymore. When discussing the moon, he talks of "tourist stuff" and "enjoying the scenery" as if we were on some dull packaged tour.

When describing the planets, he moves quickly from Mars to the outer planets because the "gas giants well justify intensive study". Comets can be "well worth investigating", while nebulae are "just pretty sites to be admired". "Photography is the best aspect of amateur astronomy in terms of producing worthwhile results with minimum effort and expertise", and radio astronomy "again is an area of astronomy where really first-class amateur observations can be of great use to professionals". "Use", "results", "worthwhile", "justify", and "professionals" . . . what happened to "wonder"?!

There is certainly a place on the market for a small inexpensive introduction to astronomy which is designed to arouse the reader's interest and help him get started in a new hobby. Unfortunately, **Astronomy for the Amateur** fails to do this job well. As inexpensive as this book is, save your money. A year's subscription to ASTRONOMY should prove much more valuable! *Thomas C. Bretl.*

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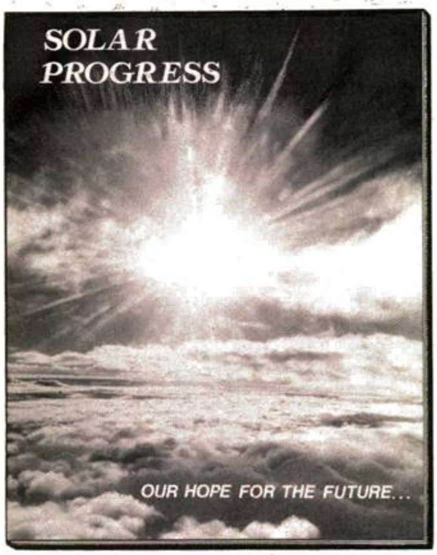

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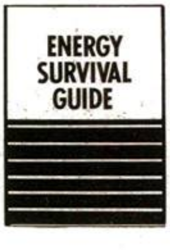

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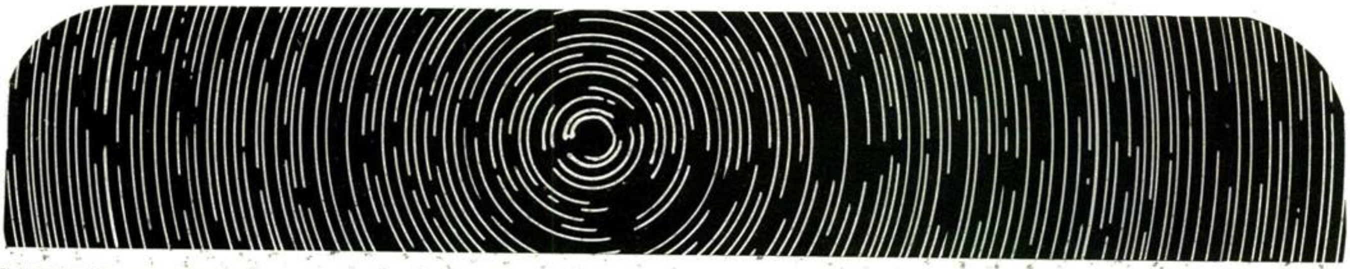


GAZER'S GAZETTE

The Southern Sky

by
Henry J. Phillips

A common affliction of most beginners' star atlases and constellation guidebooks is something we might label "northern hemisphere chauvinism". The stars, constellations and deep sky objects that are located north of declination -40 degrees are carefully and thoroughly introduced to the person who wants to know about them — in fact, often they're described in loving detail! But the large patch of sky south of this declination line is almost always glossed over, or worse, completely ignored. "If you can't see it, it doesn't exist" seems to be the philosophy behind this neglect. But the assumption that necessarily accompanies this idea — that people aren't interested in these stars just because they can't usually see them — is not only incorrect, but almost insulting.

In fact, the area of the sky that surrounds the south pole is a good deal more interesting than the corresponding area to the north! There are six northern circumpolar constellations, but more than 20 can be seen in the south. While the north has no first magnitude stars, the south has no less than six! The section of the Milky Way that crosses the northern sky is fairly dim, but the southern Milky Way contains some of the richest star fields in the galaxy. To top it all off, the southern sky contains the sky's brightest globular clusters and diffuse nebula, as well as the Milky Way's two companion galaxies and the nearest star!

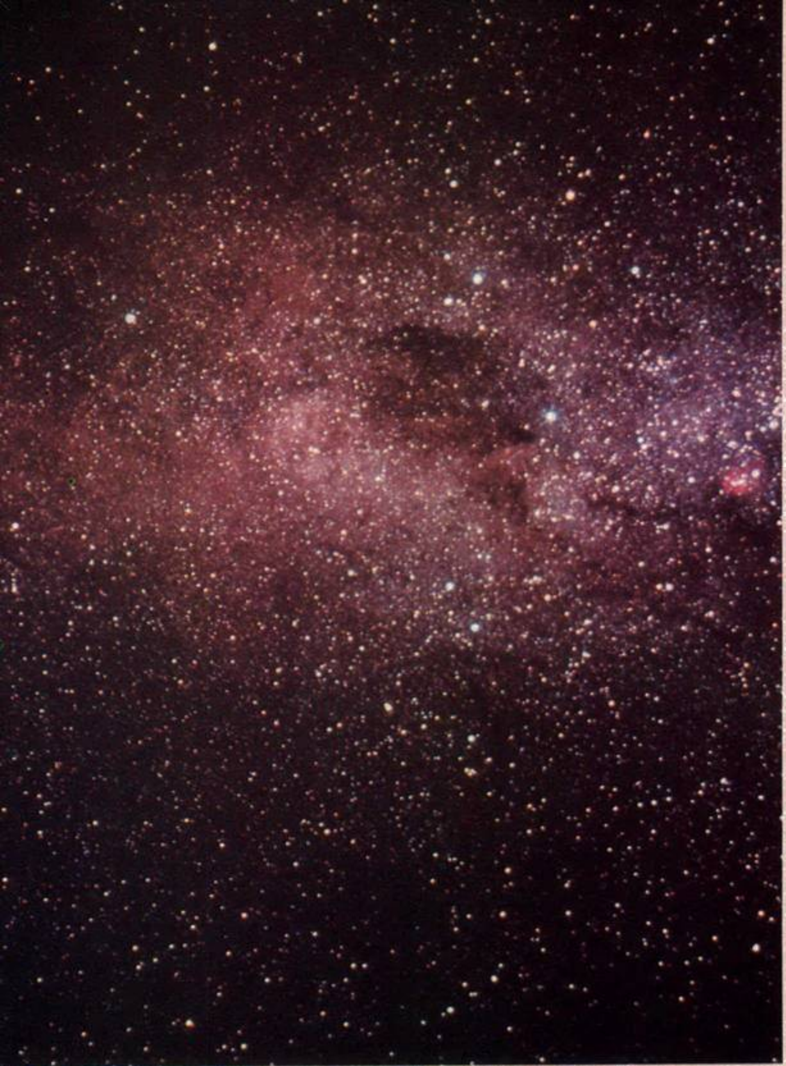
Residents of the southern United States can sometimes see a few of these marvels low above the southern horizon. The farther south you go, the more you can see; observers in Australia and southern parts of South America and Africa have these sights in their sky almost all the time. Vacationers to these areas, however, fall victim to the "chauvinism" mentioned above; since they haven't learned about the southern stars, they certainly can't find anything! Even some veteran observers can lose themselves completely among the unfamiliar southern skies. Let's take a close look at the stars of the south and at least get a short introduction; it may save you some floundering around on your next trip to far seas and shores.

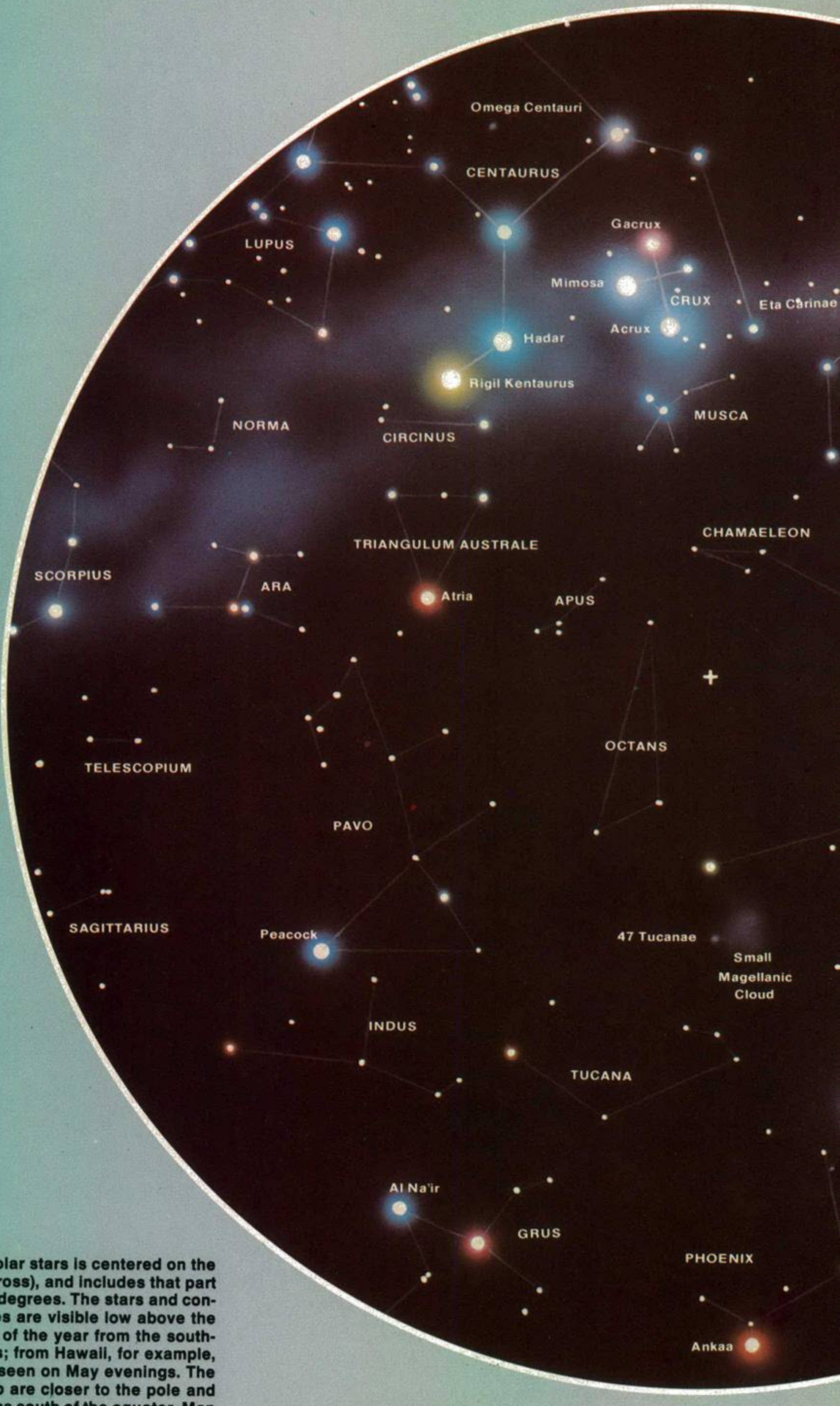
"Too many cheap little constellations!" might be your first reaction after an initial glance at a southern star chart. In contrast to the large, spreading constellations of the northern sky, the southern circumpolar stars are divided among many small groups, several of which contain little or nothing of interest to the observer. It's probably best to first learn the largest and brightest constellations, and pick up their smaller neighbors as you progress. We'll move around the pole, beginning with one of the grandest sights in the heavens: the great ship Argo.

The constellation Argo dates back to the Babylonian and Greek eras, but it was so extremely large that mapmakers of the 17th and 18th centuries began dividing it up into smaller sections to simplify the task of labeling all its stars — and there are a lot of them because Argo is positioned square on the Milky Way. Three subdivisions — Carina, Puppis and Vela — became official in 1930 when the International Astronomical Union established the constellation boundaries. Previous to that, however, Greek letters had been assigned to Argo's stars without reference to divisions, and today the three constellations share one set of Greek letters.

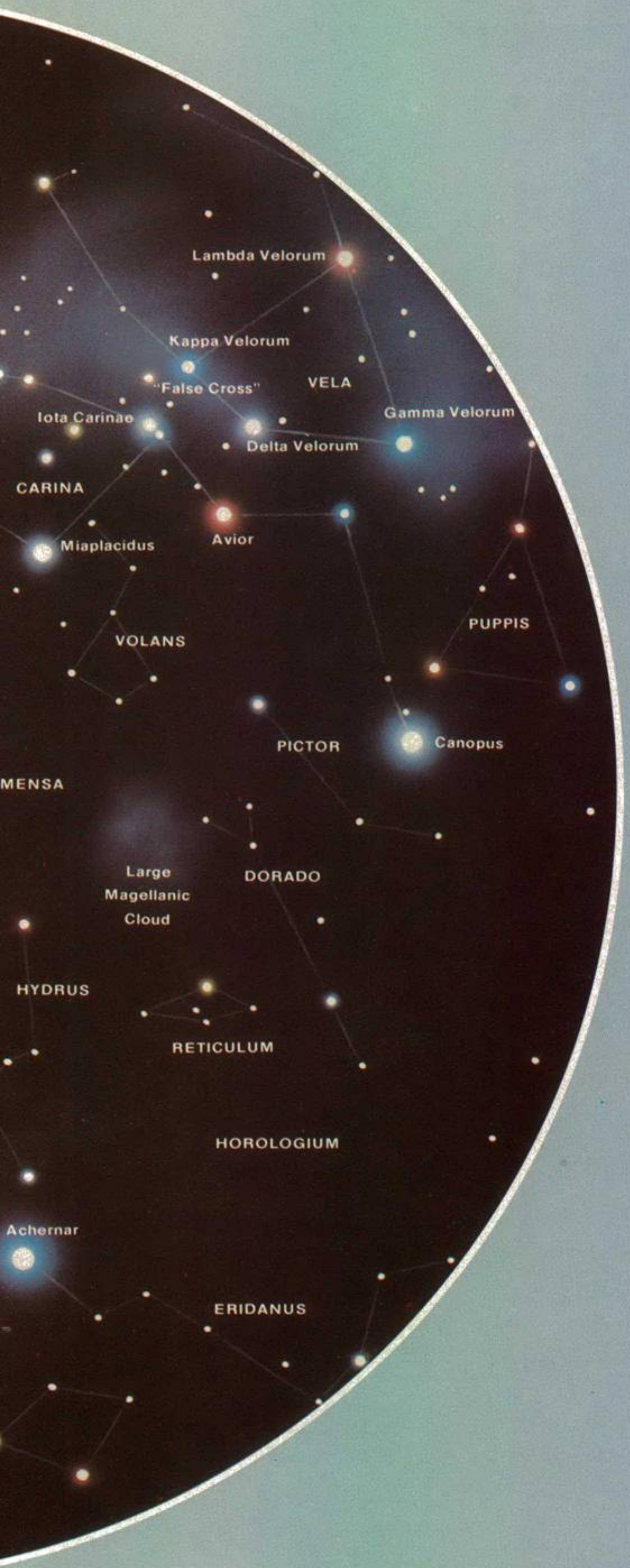
Carina contains the second brightest star in the entire heavens: Canopus, the first of the six southern first magnitude stars. Canopus is a white star of spectral class F0; lying at a distance of 98 light-years from Earth, it can be seen from as far north as Tennessee, and would probably dominate its sky area more completely if there were not so many other bright stars nearby. For instance, Carina also holds the second magnitude stars Miaplacidus (Beta Carinae), Avior (Epsilon

Top left: Some of the brightest sections of the Milky Way run across the southern circumpolar sky. Shown here is the area between Crux and Alpha and Beta Centauri; the well-known Coal Sack is prominent southeast of Crux. This is a 20 minute exposure on Fujichrome film, made with a 55mm lens at f/1.7. Top right: The largest and brightest diffuse nebula in the sky is that surrounding the star Eta Carinae. This 65 minute exposure on Fujichrome film was taken through a homemade six inch Newtonian at f/6. Bottom: The Large and Small Magellanic Clouds are two companion galaxies to our own Milky Way. This photo covers a portion of the sky about 20 degrees in extent. A 55mm lens at f/2.8 was used for this 25 minute exposure on Fujichrome film. ASTRONOMY Magazine Australia Expedition Photographs by Brad Wallis and Robert Provin, copyright © 1977 by AstroMedia Corp.




Omega Centauri
CENTAURUS
LUPUS
Gacrux
Mimosa
CRUX
Eta Carinae
Acrux
Hadar
Rigil Kentaurus
NORMA
CIRCINUS
MUSCA
CHAMAELEON
TRIANGULUM AUSTRALE
SCORPIUS
ARA
Atria
APUS
OCTANS
TELESCOPIUM
PAVO
SAGITTARIUS
Peacock
47 Tucanae
Small Magellanic Cloud
INDUS
TUCANA
Al Na'ir
GRUS
PHOENIX
Ankaa

This map of the southern circumpolar stars is centered on the south pole (marked by the small cross), and includes that part of the sky south of declination -40 degrees. The stars and constellations around the map's edges are visible low above the southern horizon at various times of the year from the southernmost parts of the United States; from Hawaii, for example, all of Centaurus and Crux can be seen on May evenings. The stars nearer the center of the map are closer to the pole and can be seen well only from locations south of the equator. Map by Adolf Schaller.



Carinae), and Iota Carinae. In neighboring Vela there are four stars of second magnitude: Gamma, Delta, Kappa and Lambda Velorum. (Note that many of the bright stars in the south don't have proper names, but only Greek letter designations.) In Puppis, the brightest is Naos (Zeta Puppis), an intensely blue star of the young spectral class O5. Scattered throughout the three constellations are hundreds of other bright stars.

Kappa and Delta Velorum and Iota and Epsilon Carinae form a figure commonly known as the "false cross" because of its resemblance to the true southern cross located a short distance east. The false cross is larger and dimmer; if you see both crosses in the sky at once, don't confuse them.

Among the smaller groups surrounding the great ship are Volans the flying fish and Pictor the easel. Pictor has only one star as bright as third magnitude (although a bright nova appeared in it in 1925). But Volans, a charming little group just west of Miaplacidus, is well worth the search. South of both is Chamaeleon the chameleon, marked primarily by a close pair of stars in its "eyes".

Moving east, we come to the figure that most people think of first when the southern stars come to mind: Crux the southern cross. Crux is the smallest of all 88 constellations, but has a lot of appeal for its small size. Two of its stars are first magnitude objects: Acrux (Alpha Crucis), which is double, and Mimosa (Beta Crucis). Both components of Acrux, as well as Mimosa, are hot blue stars of spectral class B. Gacrux (Gamma Crucis) just misses being a first magnitude star at 1.69, while Delta Crucis, the fourth member of the cross, shines at 2.81.

It's important to distinguish Crux from the false cross because the longer "bar" of Crux (marked by Gacrux and Acrux) points to the sky's south pole, while the false cross doesn't. The best way to make sure you're looking at Crux is to note the fourth magnitude star between Acrux and Delta Crucis; it looks rather like a star that has fallen off the crossing point of the two beams!

Surrounding Crux on three sides and spreading north is Centaurus, certainly a prime candidate for any "best constellation award". The view of Centaurus is simply breathtaking — no other word suffices! Leading the pack is the famous pair of first magnitude stars Alpha and Beta Centauri — which, contrary to popular belief, *do* have proper names. Alpha is Rigil Kentaurus (sometimes abbreviated to Rigilkent), and Beta is called Hadar. Rigil Kentaurus is, of course, the aforementioned nearest star; like Acrux, it is double, with yellow and orange components making a lovely color contrast. Rigil Kentaurus is only 4.3 light-years away; Hadar, by contrast, is 490 light-years away! A line from Rigil Kentaurus through Hadar will hit Crux — another handy means of identifying that important group.

SOUTHERN DEEP SKY OBJECTS

Double Stars

Star	R.A. (1950)	Dec.	Magnitudes	Separation	Comments
Beta (β) Tucanae	0^h29^m	-63°14'	4.5, 4.5	27"	each component double
Gamma (γ) Volantis	7^h09^m	-70°25'	3.9, 5.8	14"	yellow and white
Epsilon (ε) Volantis	8^h08^m	-68°28'	4.5, 8.0	6"	
Gamma (γ) Velorum	8^h08^m	-47°12'	2.2, 4.8	41"	both blue
Upsilon (υ) Carinae	9^h46^m	-64°50'	3.1, 6.0	4.6"	both white
Alpha (α) Crucis	12^h24^m	-62°49'	1.6, 2.0	4.7"	both blue
Gamma (γ) Crucis	12^h28^m	-56°50'	1.6, 6.7	110"	
Alpha (α) Centauri	14^h36^m	-60°38'	0.3, 1.7	9"	yellow and orange
Alpha (α) Circini	14^h38^m	-64°46'	3.4, 8.8	16"	
Kappa (κ) Lupi	15^h09^m	-48°33'	4.1, 6.0	27"	blue and white
Xi (ξ) Pavonis	18^h19^m	-61°31'	4.2, 8.6	3"	

Open Clusters

Object	R.A.(1950)	Dec.	Magnitude	Size	Constellation	Comments
NCG-2516	7^h59^m	-60°44'	3.5	60'	Carina	rich and concentrated
NGC-2547	8^h08^m	-49°07'	5.0	15'	Vela	50 stars, loose
IC-2391	8^h41^m	-52°45'	2.6	40'	Vela	loose and scattered
IC-2395	8^h43^m	-48°00'	4.6	10'	Vela	intermediate rich
NCG-3114	10^h01^m	-59°53'	4.5	30'	Carina	100 stars
IC-2581	10^h25^m	-57°23'	5.2	5'	Carina	small, fairly rich
IC-2602	10^h41^m	-64°08'	1.6	70'	Carina	intermediate rich
NGC-3532	11^h03^m	-58°24'	3.5	60'	Carina	large and rich
NGC-3766	11^h34^m	-61°19'	4.5	10'	Centaurus	rich and concentrated
NGC-4755	12^h50^m	-60°05'	5.0	10'	Crux	"Jewel Box"; many different colored stars
NGC-5822	15^h01^m	-54°09'	6.5	40'	Lupus	large and scattered
NGC-6025	15^h59^m	-60°22'	6.0	10'	Triangulum Australe	fairly loose
NGC-6087	16^h14^m	-57°47'	6.0	20'	Norma	fairly loose
NGC-6193	16^h37^m	-48°40'	5.5	20'	Ara	intermediate rich

Globular Clusters

Object	R.A.(1950)	Dec.	Magnitude	Size	Constellation	Comments
NGC-104	0^h21^m	-72°21'	4.5	23'	Tucana	47 Tucanae; very large and bright; in SMC
NGC-362	1^h00^m	-71°07'	8.0	5'	Tucana	concentrated; in SMC
NGC-2808	9^h10^m	-64°39'	8.0	6'	Carina	bright and very rich
NGC-4833	12^h56^m	-70°36'	8.5	5'	Musca	large and rich
NGC-5139	13^h23^m	-47°03'	4.0	23'	Centaurus	Omega Centauri; largest, brightest globular
NGC-6397	17^h36^m	-53°38'	7.5	19'	Ara	very large and rich
NGC-6572	19^h06^m	-60°04'	7.0	13'	Pavo	bright and very large

Diffuse Nebulae

Object	R.A.(1950)	Dec.	Magnitude	Size	Constellation	Comments
NGC-2070	5^h39^m	-69°04'	8.5	20'x20'	Dorado	Tarantula nebula; in LMC
NGC-3324	10^h35^m	-58°22'	8.4	15'x14'	Carina	pretty bright and large
NGC-3372	10^h43^m	-59°25'	3.5	85'x80'	Carina	Eta Carinae nebula; most prominent in entire sky
IC-2944	11^h33^m	-62°44'	4.0	66'x36'	Centaurus	surrounds Lambda Centauri
NGC-6188	16^h35^m	-48°55'	5.3	19'x12'	Ara	large and irregular

Planetary Nebulae

Object	R.A.(1950)	Dec.	Magnitude	Size	Constellation	Comments
NGC-2867	9^h20^m	-58°06'	9.5	13"x11"	Carina	very small and round
NGC-3195	10^h10^m	-80°37'		44"x33"	Chamaeleon	bright and elliptical
NGC-3918	11^h47^m	-56°54'	8.5	13"	Centaurus	small, round and blue

Galaxies

Object	R.A.(1950)	Dec.	Magnitude	Size	Constellation	Comments
SMC	0^h50^m	-73°	1.5	3.6°	Tucana	companion of Milky Way; irregular
NGC-1313	3^h17^m	-66°40'	10.5	4.5'x3'	Reticulum	elliptical
NGC-1553	4^h15^m	-55°54'	10.5	2.3'x2'	Dorado	spiral
NGC-1566	4^h18^m	-55°04'	10.5	8'x6'	Dorado	spiral
LMC	5^h26^m	-69°	0.5	7.2°	Dorado, Mensa	companion of Milky Way; irregular?
NGC-4945	13^h02^m	-49°01'	9.5	11.5'x2'	Centaurus	spiral
NGC-5128	13^h22^m	-42°45'	7.5	10'x8'	Centaurus	"Centaurus A"; peculiar
NGC-6744	19^h05^m	-63°56'	10.0	9'	Pavo	spiral

The rest of Centaurus extends much farther north (it is actually our ninth largest constellation) and contains so many bright stars that once seen, it's not readily forgotten. Abutting on its eastern edge is Lupus the wolf, another superb collection of stars that certainly must rank among the "best and the brightest" in the sky. Lupus' brightest stars bear a slight resemblance to the keystone of Hercules; the group lies on the western fringes of the summer Milky Way.

Other groups nearby are Musca the fly (the only insect in the sky), a graceful group south of Crux, and Circinus and Norma, two shapeless groups in the Milky Way south of Lupus. Across the Milky Way from Lupus is Triangulum Australe, the southern triangle, bigger and brighter than its northern namesake. Atria (Alpha Trianguli Australis) is this group's brightest star. South of the southern triangle near the pole is Apus the bird of paradise, a small compact group of fourth magnitude stars. In the Milky Way just south of Scorpius is another excellent constellation, Ara the altar, which is rich in star clusters and bright starclouds.

So far we've described half of the southern sky, noting many bright stars and prominent star groups. The stars on the opposite side of the pole are less bright and less interesting — an extension of the star-poor regions of the autumn sky familiar to us. Southeast of Ara is Pavo the peacock, marked by a triangle of fairly bright stars; the brightest is called Peacock (Alpha Pavonis). Surrounding Pavo are Telescopium the telescope, Indus the Indian and Octans the octant — all quite lacking in interest (although Octans does have the distinction of containing the south celestial pole within its boundaries — a pole unmarked by any prominent star equivalent to Polaris). More interesting are Grus the crane, Tucana the toucan, and Phoenix the firebird, three constellations that have at least recognizable patterns. Grus' brightest star, Al Na'ir (Alpha Gruis), is second magnitude, ranking 30th among all the stars in brightness.

A large triangle of third magnitude stars marks Hydrus the water snake, east of Tucana, and just north of Tucana is the isolated first magnitude star Achernar — the southern end of the river Eridanus. Achernar, 10th brightest of our stars, is a blue star of spectral class B3, located 118 light-years away. Completing our tour around the pole is another collection of dim star groups: Horologium the clock, Reticulum the net, Dorado the goldfish, and Mensa the mountain. Mensa gets our nomination for the sky's dimmest constellation: None of its stars are brighter than fifth magnitude!

In this brief run-through of the southern constellations, we've mentioned the Milky Way a number of times. In fact, the Milky Way is at its brightest and most glorious in the south; only the starclouds of Sagittarius are more luminous. Sweeping through Puppis, Vela and Carina with binoculars or an RFT is a marvelous experience, and the galaxy in Centaurus, Lupus and Norma is simply indescribable. Interrupting the Milky Way's flow at Crux is the most famous of the dark nebulae — the well-known "Coal Sack", which resembles a hole in the stars of the galaxy just southeast of the southern cross.

In the dimmer half of the southern sky are what appear to be two detached portions of the Milky Way. Actually these are the Large and Small Magellanic Clouds — the Milky Way's two companion galaxies. Investigation of these two regions will reveal myriad clusters and nebulae — all located outside our own galaxy! Located in the SMC is NGC-104 (also called 47 Tucanae), the second largest and brightest globular cluster in the sky. Another prominent globular in the SMC is NGC-362. In the LMC are many objects that have their own NGC numbers; the best of these is NGC-2070, known as the Looped or Tarantula nebula — a huge diffuse nebula similar to M-42.

Also worthy of special mention is NGC-3327, the famous Eta Carinae nebula. NGC-3327 is the largest and brightest diffuse nebula in the entire sky — superior even to the Orion and Lagoon nebulae. At its heart is the peculiar variable star Eta Carinae, a star that some astronomers believe may be on the verge of exploding as a supernova. The nebula curves out from the central portions in three clearly defined sections; altogether it is one of the sky's most thrilling sights.

If NGC-104 ranks second among globular clusters, what's first? The answer is another southern object: NGC-5139, otherwise known as Omega Centauri. This globular cluster is visible even to the naked eye as a fuzzy spot; it's resolvable around the edges in an RFT, and larger telescopes show a swarm of thousands of stars. NGC-5139 is one of the nearest globular clusters, which certainly helps account for its brightness.

Other southern deep sky objects of interest are listed in the table on page 38 . This list only scratches the surface; many more clusters, nebulae and galaxies are well worth the effort to search for them. As with any area of the sky of this size, some sections are simply choked with interesting and beautiful stars, clusters and nebulae, while others are seemingly barren and devoid of objects. But taken as a whole, the southern circumpolar sky is one of the most fascinating regions of the heavens. Even if you never get a chance to witness it first hand, take a little time to learn what's "down there" from descriptions or photographs. If you can get your telescope to the southern part of the globe someday, you're in for a real treat!

Editor's Note: ASTRONOMY would be pleased to receive observation reports or photographs of constellations or deep sky objects from southern hemisphere residents or visitors.

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5 - Series 1 KELLNER EYEPIECES (1-1/4" O.D.) - Highly corrected, 3-element design, fully coated. The best in moderately priced eyepieces. Barrels threaded for our filters. **Focal lengths: 6, 12, 25mm each...$12.50 ppd. - 40mm Wide Field...$14.50 ppd.**

6. - KELLNER 40mm EXTRA-WIDE-FIELD (1-1/4" O.D.) - Yields widest field obtainable in 1-1/4" O.D. Enlarged field lens and special field-flattening optics with long eye relief. Barrel accepts our filters... **$22.75 ppd.**

7 - Series 1 ERFLE 20mm (1-1/4" O.D.) - An advanced 5-element system with fully coated, color corrected optics. Wide 65° field. Barrel accepts our filters. **$23.95 ppd.**

8 - ZOOM ORTHOSCOPIC EYEPIECE (1-1/4" O.D.) - Zooms instantly from 8.4mm to 21mm, with excellent image corrections at all powers. Wide 50° field at 8.4mm. Fully coated optics...**$32.95 ppd. - Filter adapter #004:** couples our filters to above eyepiece...**$1.00 ppd.**

9 - ZOOM KELLNER EYEPIECE (.965" O.D.) - Fine 4-element design. Zoom range 7.5mm-22.5mm. Fully coated optics...**$24.95 ppd.**

SUPER-WIDE-FIELD EYEPIECES (2" O.D.) - Premium-quality wide-field eyepieces for 2" focusers. The ultimate in rich-field performance. Fully coated.
10 - ERFLE 32mm (2" O.D.) - Sophisticated 5-element optical system. Wide, flat 65° field...**$67.50 ppd.**
11 - KELLNER 60mm (2" O.D.) - Low power, long eye relief. Ideal for deep-space observations...**$42.50 ppd.**

12 - ERFLE 32mm (1-1/4" O.D.) - As in (10), but with standard 1-1/4" barrel, threaded for our filters. 60° field...**$67.50.**

13 - .965" EYEPIECES - (phone, or request catalog, for details).

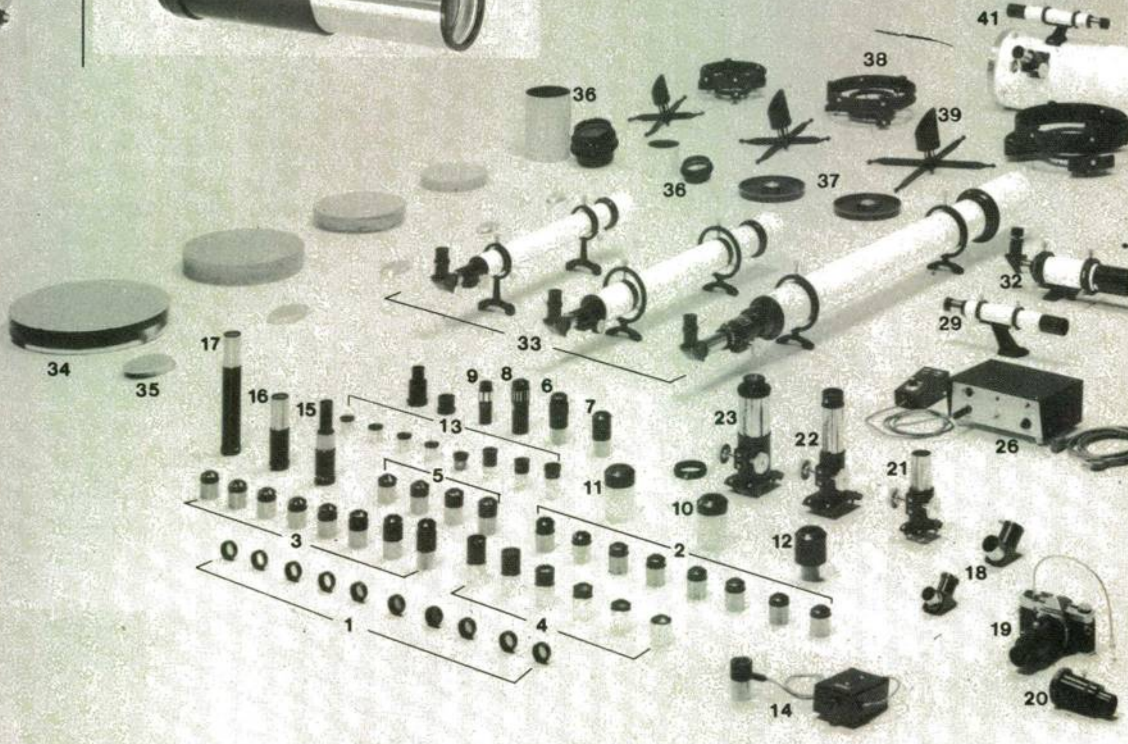
14 - ILLUMINATED RETICLE GUIDING EYEPIECE (1-1/4" or .965" O.D.) - For professional-level photographic guiding. Kellner 12mm optical system, with precisely focusable 4-line glass reticle. Remote brightness control and 3 ft. cable. (Extension cables available) Complete...**$37.50 ppd.**
Micrometer Reticle: Full-field scale for accurate measurements of double star separations, planetary angular diameters, etc. Interchanges with standard 4-line reticle...**$11.95 ppd.**

15 - 2X ACHROMATIC BARLOW LENS (1-1/4" O.D.) - A high resolution, coated, negative achromat with excellent corrections for spherical and chromatic aberrations. **$18.75 ppd.**

16, 17 - 2X AND 3X TELENEGATIVE AMPLIFIERS (1-1/4" O.D.) - The world's finest Barlow lenses. Full 26mm clear aperture, with virtually flawless optical corrections at all photo-visual wavelengths. Produces optimum performance on telescopes of any focal ratio. Fully coated. (16) **2X Model 122...$29.50 ppd.** (17) **3X Model 123...$32.50 ppd. - Combination 2X and 3X Model 124...$39.50 ppd.**

18 - DIAGONAL PRISMS - Quality, right-angle prisms, fully coated. **1-1/4" O.D....$14.95 ppd. - .965" O.D....$10.95 ppd.**

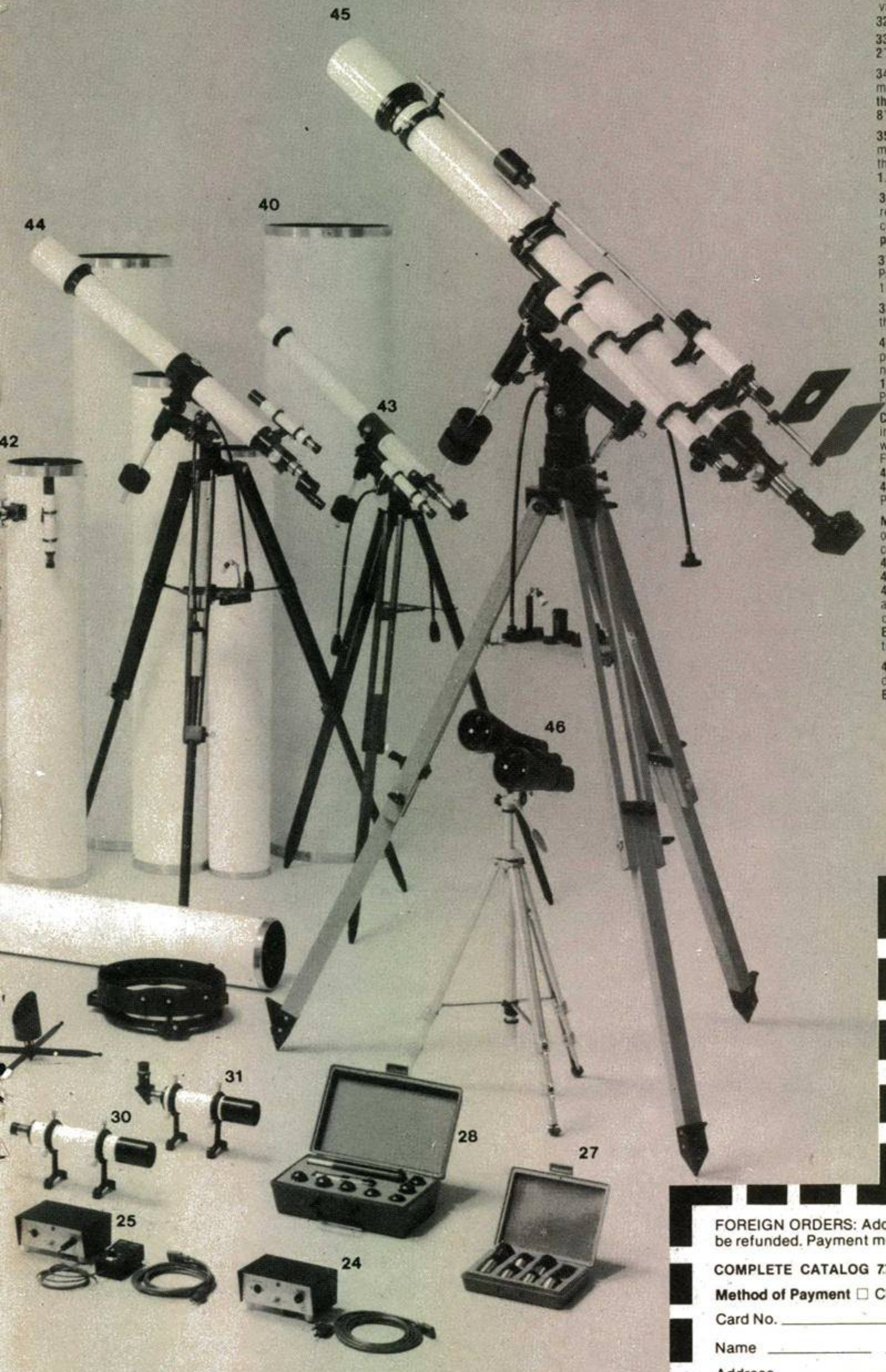
19 - OLYMPUS OM-1 ASTROCAMERA - One of the world's great astrocameras. (Phone or request catalog for details.)...**From $229.50.**



20 - DELUXE CAMERA ADAPTERS - Adapt your camera to telescope focuser instantly. Individually machined from solid bar aluminum. All units permit both eyepiece projection and first (prime) focus photography. Specify either .965'' or 1-1/4'' focuser. (If for Celestron, please specify.) All 1-1/4'' units are threaded for our filters. **Pentax, Praktica, Yashica, Mamiya...$15.95 ppd. - Exakta, Nikon, Canon, Minolta, Miranda, Konica...$23.95 ppd. - Olympus OM-1...$24.95 ppd.**

RACK-AND-PINION FOCUSERS - Precision metal construction. All 3 models include helical-cut rack for ultra-smooth focusing without backlash. Universal bases fit all tube sizes. Standard 1-1/4'' eyepiece holders. **Each focuser is guaranteed to be the finest obtainable in its class.**
21 - Model #67 - Strong, lightweight design for 4'' to 10'' telescopes. 2-3/16'' travel. An excellent value...**$14.75 ppd.**
22 - Model #640 - A heavy-duty deluxe focuser for 6'' to 16'' telescopes. Full 3'' travel for both visual and photographic applications...**$21.75 ppd.**

23 - Model #680 - Our finest focuser. Accepts both 1-1/4'' and 2'' eyepieces. Full 3'' travel for photo or visual observing with 6'' to 16'' telescopes...**$29.95 ppd.**



VARIABLE FREQUENCY DRIVE CORRECTORS - Quality, temperature compensated circuitry for precise electronic guiding. Each model will drive telescopes to 14'' aperture. 20 ft. battery cables, instructions included.
24 - Model #24 - Uses 12v. D.C. Frequency variable between 50-70Hz with knob attached to power box. An excellent value...**$49.50 ppd.**
25 - Model #29 - Uses 12v. D.C. Remote control box with fast-slow buttons and variable center frequency dial for tracking at solar, lunar, or planetary rates...**$62.50 ppd.**
26 - Model #33 - Uses 12v. D.C. or 110v. A.C. Other features identical to Model 29...**$89.50 ppd.**

ACCESSORY CASES - Rugged polyethylene, for dust-free protection of eyepieces, filters, Barlows, etc. For either 1-1/4'' or .965'' accessories. Die-cut foam lining.
27 - Model #51 - 7'' x 8-1/2''...$7.95 ppd.
28 - Model #54 - 8'' x 12''...$10.95 ppd.

VIEWFINDERS - Each with coated, achromatic objective and crosshair eyepiece.
29 - 6 x 30mm: Fine, 4° wide-field finder. Thousands now in use. 2-ring bracket included...**$14.75 ppd.**
30 - 8 x 50mm - Large 50mm aperture. Ke30mm Extra-Wide-Field crosshair eyepiece. Sharp, brilliant images... **$25.95 ppd. - Brackets: $7.95/Pr.**
31 - 8 x 50mm Right-Angle - 50mm aperture, for both straight-through and right-angle viewing. Prism included... **$30.95 ppd. - Brackets: $7.95/Pr.**
32 - 8 x 50mm Right-Angle - As above, but with bracket for Celestron 8... **$42.50 ppd.**
33 - PHOTO-GUIDE TELESCOPES - (Phone or request catalog for details.) **2''...$39.50 - 2.4''...$65.00 - 3.1''...$138.00**

34 - PARABOLIC PRIMARY MIRRORS - Professional quality hand figured Pyrex mirrors, aluminized and quartz overcoated. **Each mirror is guaranteed to reach all theoretical limits of performance. 6'' f/8...$49.95 ppd. - 10'' f/6...$134.95 ppd. 8'' f/6 or f/7.5...$79.95 ppd. - 12-1/2'' f/6...$239.95 ppd.**

35 - ELLIPTICAL SECONDARIES - For optimum performance with any primary mirrors. Aluminized, overcoated. As optically flat as master opticians can make them. Minor axis sizes shown, postpaid: **1.30''...$9.00 - 1.52''...$12.50 - 1.83''...$14.50 - 2.14''...$17.50 - 2.60''...$21.00**

36 - OBJECTIVE LENSES - As used in Meade guide telescopes and equatorial refractors. Air-spaced, achromatic, fully coated. Mounted in machined, threaded cells. Dewcap and dustcap included. **2'' f/12...$19.50 ppd. - 2.4'' f/15...$34.50 ppd. - 3.1'' f/15...$74.50 ppd.**

37 - SETTING CIRCLES - Die-cast aluminum, 6'' diameter. Machine engraved. Precision guaranteed. Standard 1-1/2'' bore...**$35.00/pr.** Other bores (from 1/4'' to 2''): **add $1.50 per circle.**

38, 39 - MIRROR CELLS AND SPIDERS/DIAGONAL HOLDERS are available to fit the tubing below. Phone, or request catalog, for details.

40 - FIBERLITE TELESCOPE TUBES - 20% more rigid, yet 40% lighter, than pure fiberglass, with low thermal conductivity. Polished end rings available at nominal cost. Partial price list: **7'' I.D. x 50''...$36.00 - 9-1/4'' I.D. x 60''...$49.50 12-3/8'' I.D. x 62''... $68.00 - 12-3/8'' I.D. x 72''...$76.00**
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COMPLETE OPTICAL TUBE ASSEMBLIES - Fully Assembled. Each assembly includes the premium quality Meade components described above: Fiberlite tube with end rings, primary mirror and cell, spider and secondary mirror, Model #67 Focuser, 6 x 30mm viewfinder. Shipping charges collect.
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Outer Planets Approach Opposition

November Satellites of Jupiter
1:00 a.m. EST, 10:00 p.m. PST

1	43021	• • ●• •	16	43210	• • • • ●
2	43210	• •• •●	17	4320	• ••●
3	4102	• •●•	18	4032	• ● ••
4	04123	●• • • •	19	41203	• ••● •
5	12043	•• ● • •	20	24013	••●• •
6	20134	• ●•• •	21	13042	••●••
7	13024	•• ● • •	22	30124	• ●•• •
8	30214	• ●• • •	23	32104	• ••● •
9	32104	• • •● •	24	32014	••●• •
10	204	•● •	25	10324	•● •• •
11	0234	● •••	26	1034	•● • •
12	12043	••●• •	27	20134	• ● • • •
13	24013	•• ● • •	28	1024	•● • •
14	41302	• ••● •	29	34012	• •● ••
15	43012	• • ● ••	30	34210	•• ••●

The four major satellites of Jupiter orbit the planet in periods ranging from less than two days to 17 days. You can see them change position from one night to the next; their motions are often evident after only a few hours' observation. You only need a small telescope to detect all four, and you can frequently make out several in rigidly held (or tripod mounted) binoculars. This table shows the approximate positions of the moons at about 3 a.m. EDT on the mornings indicated. The first column on the left shows the date; the second column identifies the moons by their positions relative to Jupiter's disk (1 =Io, 2 =Europa, 3 =Ganymede, 4 =Callisto, 0 =Jupiter's disk). The third column gives the satellites' positions as they appear through a telescope. The orientation of the satellite is given with south up as seen through a standard inverting telescope.

The evening sky, which has been barren of planets since early summer, begins welcoming them back this month as Jupiter and Mars gradually rise and become prominent earlier in the night. Over the next few months, the naked eye planets — which as recently as September were all clustered in the morning sky — will return to the evening, again visible to those observers who have been too tired to climb out of bed before dawn every morning since July.

Venus

Drawing closer to the sun, Venus now rises only about an hour before dawn (as compared to almost four hours in August). Its magnitude has shrunk to -3.4 — about as dim as Venus ever gets, although of course it still outshines everything in the sky except the sun and moon. By mid-December, Venus will be too close to the sun to be seen; it will reappear in the evenings in early 1978.

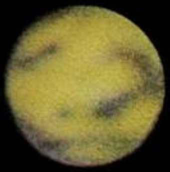
Venus will be only 0.1 degree away from the crescent moon on Nov. 9; it'll be fun to watch the moon creep up on and pass the bright planet be-

Four solar system objects — including the -2 magnitude Perseid meteor streaking to its death in Earth's atmosphere — are captured in this one minute exposure on Ektachrome 200 film, obtained with a 55mm lens at f/1.7. The crescent moon (with Earthshine) is seen at the bottom of the photo; clearly delineating the ecliptic above it are Venus and Jupiter. The stars of *Gemini and Taurus provide a backdrop to* this remarkable shot. Photograph by James R. Westlake Jr.

Planet Finder

Ⓒ Ceres

Nov.	1	15
R.A.	15h19m	15h42m
Dec.	-14°57'	-16°47'
Mag.	+9.0	+9.0



Ⓐ Mercury

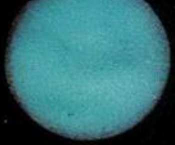
Nov.	1
R.A.	15h01m
Dec.	-17°57'
Mag.	-0.6

Ⓑ Mercury

Nov.	15
R.A.	16h29m
Dec.	-23°52'
Mag.	-0.3

Ⓜ Mars

Nov.	1	15
R.A.	8h20m	8h41m
Dec.	+21°01'	+20°18'
Mag.	+0.4	+0.2



Ⓝ Neptune

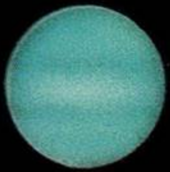
Nov.	15
R.A.	16h55m
Dec.	-21°11'
Mag.	+7.7

SUN

The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

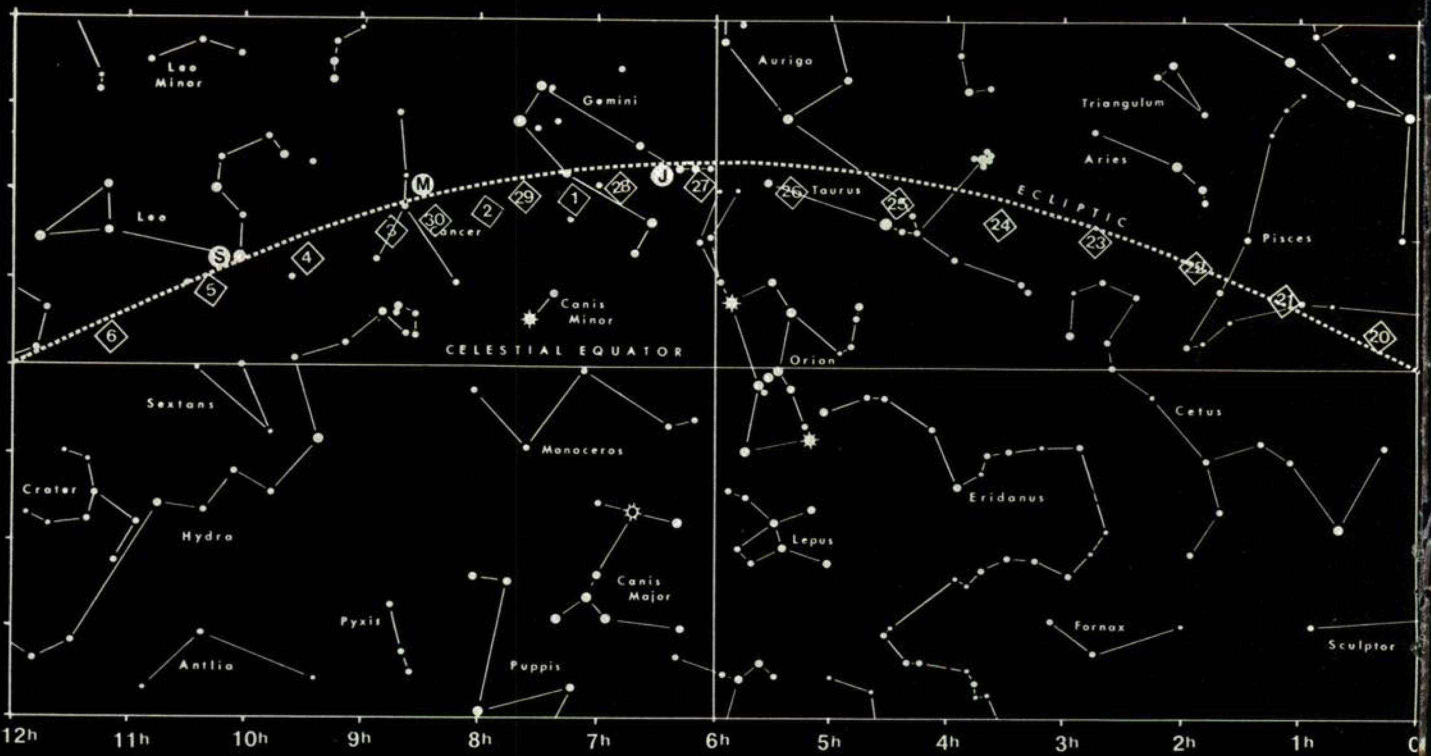
Ⓢ Saturn

Nov.	1	15
R.A.	10h06m	10h09m
Dec.	+12°53'	+12°39'
Mag.	+0.8	+0.8



Ⓤ Uranus

Nov.	15
R.A.	14h41m
Dec.	-15°19'
Mag.	+5.7

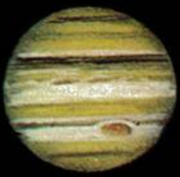

Leo Minor
Gemini
Aurigo
Triangulum
Aries
Leo
M
J
S
Cancer
Taurus
ECLIPTIC
Pisces
Canis Minor
CELESTIAL EQUATOR
Orion
Sextans
Cetus
Monoceros
Crater
Eridanus
Hydra
Lepus
Canis Major
Pyxis
Fornax
Sculptor
Antlia
Puppis
1
2
3
4
5
6
20
21
22
23
24
25
26
27
28
29
30
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec. = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag. = magnitude, a

November 1977

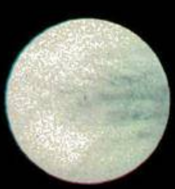
Ⓥ Vesta

Nov.	1	15
R.A.	13h06m	13h32m
Dec.	-1°30'	-3°58'
Mag.	+8.5	+8.4



Ⓙ Jupiter

Nov.	1	15
R.A.	6h26m	6h23m
Dec.	+22°57'	+23°00'
Mag.	-2.1	-2.2



Ⓨ Venus

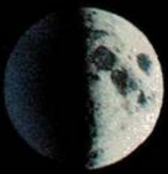
Nov.	1
R.A.	13h15m
Dec.	-6°18'
Mag.	-3.4

Ⓩ Venus

Nov.	15
R.A.	14h21m
Dec.	-12°41'
Mag.	-3.4

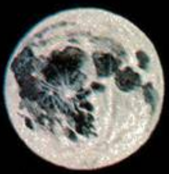
Ⓟ Pluto

Nov.	15
R.A.	13h21m
Dec.	+9°23'
Mag.	+14



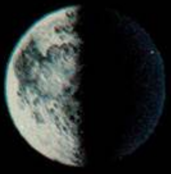
First Quarter

November 17



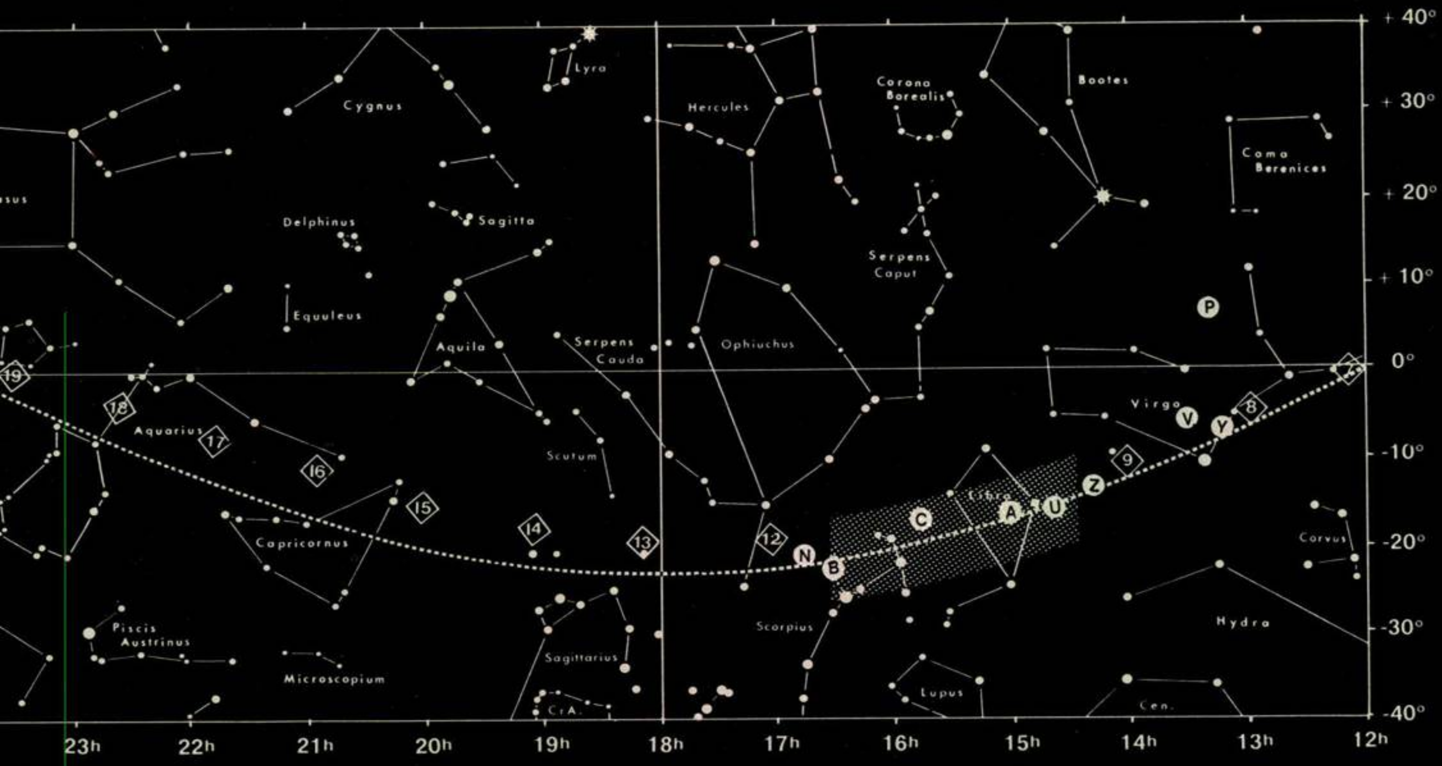
Full Moon

November 25



Last Quarter

November 3


+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
Lyra
Cygnus
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
Virgo
Aquarius
Scutum
Libra
Capricornus
Scorpius
Corvus
Hydra
Piscis Austrinus
Sagittarius
Microscopium
Lupus
CrA.
Cen.
V
Y
Z
P
C
A
U
N
B
8
9
12
13
14
15
16
17
18
19
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

tween about the 7th to the 10th, its crescent shrinking as it goes. Try to obtain photographs of this close approach; the crescent moon in conjunction with a planet is always a pretty sight.

Satellite Shadows on Jupiter

Date	Satellite	Transit Begins (EST)	Transit Ends (EST)
Nov. 1	2	3:30 a.m.	6:09 a.m.
1	1	4:40 a.m.	6:51 a.m.
2-3	1	11:08 p.m.	1:19 a.m.
8	2	6:06 a.m.	8:46 a.m.
8	1	6:33 a.m.	8:45 a.m.
10	1	1:01 a.m.	3:13 a.m.
11	2	7:25 p.m.	10:05 p.m.
11	1	7:30 p.m.	9:41 p.m.
17	1	2:55 a.m.	5:07 a.m.
18	1	9:23 p.m.	11:35 p.m.
18-19	2	10:02 p.m.	12:42 a.m.
24	1	4:48 a.m.	7:00 a.m.
25-26	1	11:17 p.m.	1:29 a.m.
26	2	12:39 a.m.	3:19 a.m.
27-28	3	10:31 p.m.	1:25 a.m.

1 = Io
2 = Europa
3 = Ganymede
4 = Callisto

Mars

Because it's so extremely red, Mars is apt to startle people who have never seen it before. Its red color stands out especially well when the planet is approaching opposition and is at its brightest. Mars will reach opposition next January, so watch it climb rapidly in brightness over the next two months, becoming more strongly colored to the naked eye as it does so. During November, Mars' magnitude climbs all the way from +0.4 on the 1st to -0.1 on the 30th!

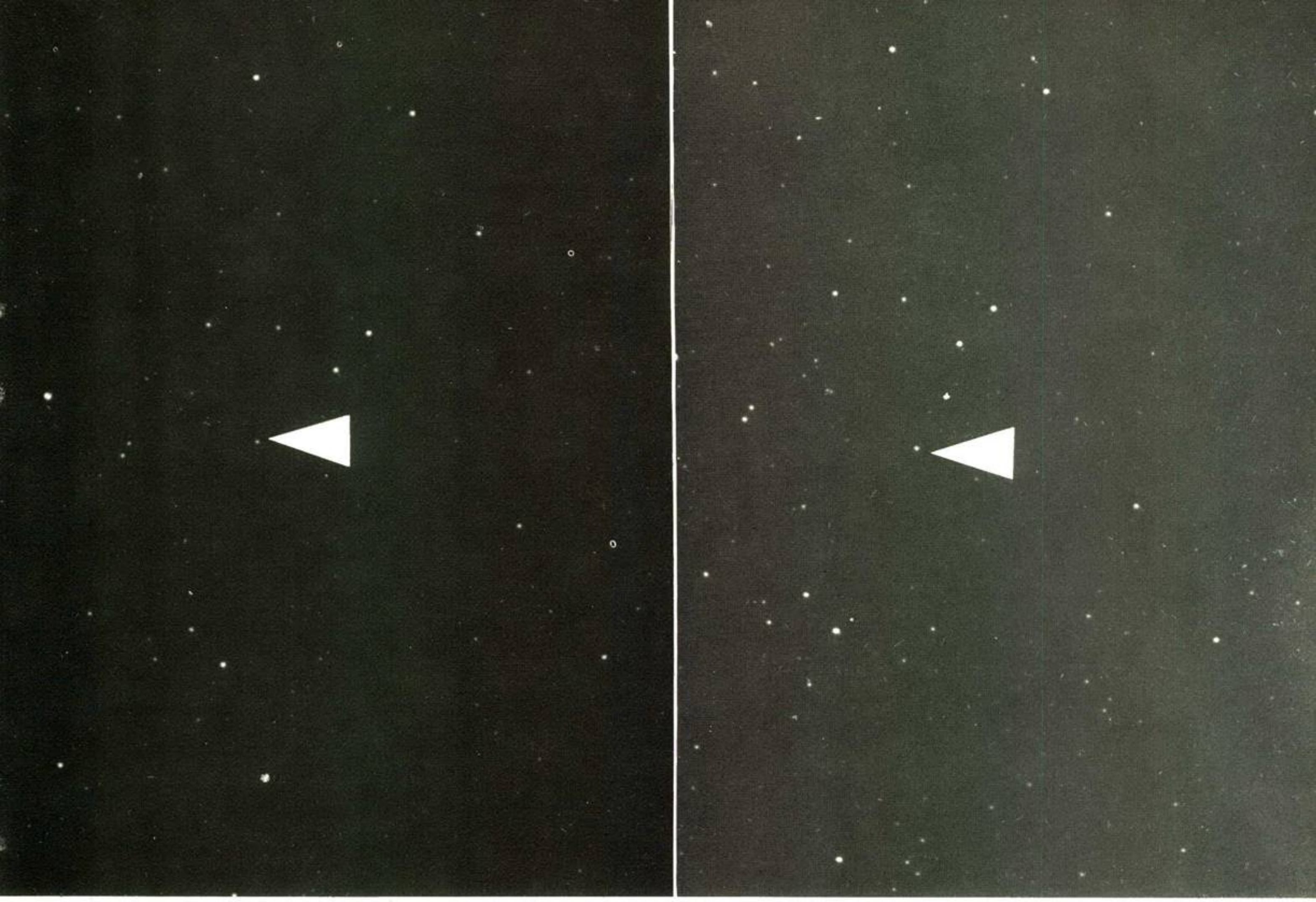
Mars is located in the constellation Cancer this month. Be sure to watch it on the evening of the 12th, when it will be passing through M-44, the Beehive cluster. Take a look at Mars every night from about the 10th to the 17th to see it pass up to and across M-44. Photographs of this event — or of Mars in the Beehive — would be welcome at ASTRONOMY.

As Mars' distance from Earth decreases from 100 million miles (160 million kilometers) to 80 million miles (130 million kilometers), its apparent diameter grows from 8.6 to 10.6 seconds of arc. Telescopic observation of Mars should begin revealing more than a small red dot; watch especially for the north polar cap, which should be easily detectable this fall. Be on the alert for dark markings also.

The waning gibbous moon will pass seven degrees south of Mars on Nov. 3, and again on Dec. 1.

Jupiter

The largest planet is nearing op-



One reason observation of the various members of the solar system is so enjoyable is that we can watch them move across the sky, slowly changing their positions from one night to the next. The photographs on these pages demonstrate planetary motions. Opposite, left: On July 23, Venus, Jupiter and Mars could all be easily seen in the predawn sky; this photo, from the optical site of the Goddard Space Flight Center in Greenbelt, Md., shows Venus and Jupiter above and to the left of the observatory dome, with Mars farther up in the sky, above the "V" of the Hyades. This is a 60 second exposure on High Speed Ektachrome, made through a 50mm lens at f/1.4. Opposite, right: Five days later, Venus had moved much nearer Jupiter, while Mars had drawn closer to the Hyades, its color and brightness making an almost perfect match with the first magnitude star Aldebaran. This 30 second exposure on High Speed Ektachrome was taken through a 50mm lens at f/2. Photographs by Fred Espenak. Above: About a month before opposition, asteroid 21 Lutetia (featured in the July 1977 Gazer's Gazette article on tracking asteroids) was photographed as it moved through a field in the constellation Aquarius. These photographs (each covering an area of about 1-1/2 square degrees) show the 10th magnitude asteroid's motion from July 19 (left) to July 20 (right). Both photos are 30 second exposures on Tri-X, obtained with the 14 inch Celestron at MacLean Observatory, Sierra Nevada College, Incline Village, Nev. Photographs by Dr. Leo Connolly.

position, which it will reach this year three days before Christmas. Like Mars, it is growing in brightness and apparent size; during most of November, Jupiter's magnitude is -2.2, while its angular diameter increases to 43.5 seconds of arc.

Jupiter is situated in the western ramparts of Gemini this month, inside the great circle of first magnitude stars that marks the winter sky. The just-past-full moon will pass five degrees south of the planet on Nov. 1 and again on Nov. 28.

Saturn

Situated in Leo near the bottom of the sickle, Saturn rises about midnight during November. It will pass less than one degree north of Regulus on the morning of Nov. 3; again, it's fun to watch the planet close in on and pass the star. At magnitude +0.8, Saturn will be slightly brighter than the +1.3 magnitude star. The last quarter moon will be five degrees south of the ringed planet on Nov. 5.

Saturn's distance from Earth decreases from 883 million miles (1,420 million kilometers) to 839 million miles (1,349 million kilometers) as the angular diameter of its disk grows from 15.7 to 16.5 seconds of arc. The angular diameter of its rings is close to 40 seconds of arc all month.

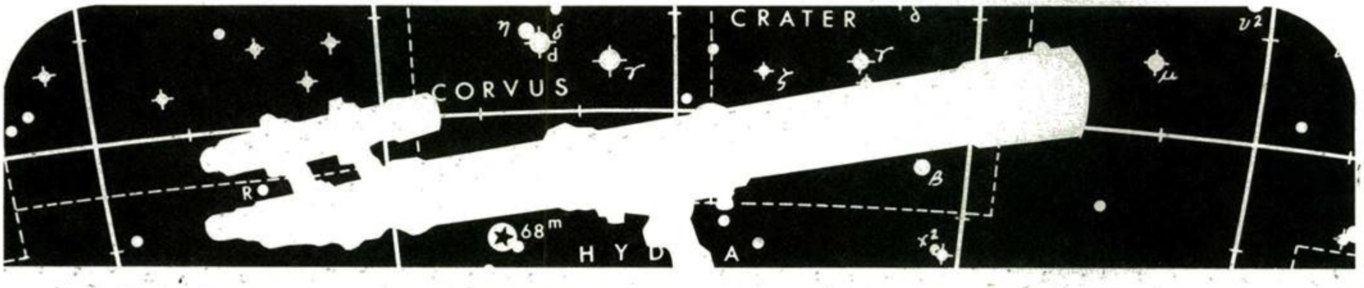
Mercury

Although it is in the evening sky all month (having passed superior conjunction on Oct. 18), Mercury is too close to the sun to be readily seen. You might try scanning low above the southwestern horizon with binoculars during the last few days of November to see if you can pick up this elusive planet. Mercury will be at greatest eastern elongation on Dec. 3.

Meteors

Two meteor showers reach maximum during November: the Taurids and the Leonids. The Taurids are a long spreading shower with no clearly defined peak; they will be at their best around Nov. 4. Unfortunately, the light of the last quarter moon should effectively drown out all but the brightest of these slow-moving meteors.

The Leonids are an erratic shower, giving good displays some years and appearing almost "dead" in others. They will peak on Nov. 16 and 17; this time the moon will be at first quarter, so it will have set by midnight and will not interfere with observation. In contrast to the Taurids, the Leonids are among the most rapid of meteors. Why not take a look this year and see what the Leonids decide to do?



EQUIPMENT ATLAS

Measuring Double Stars

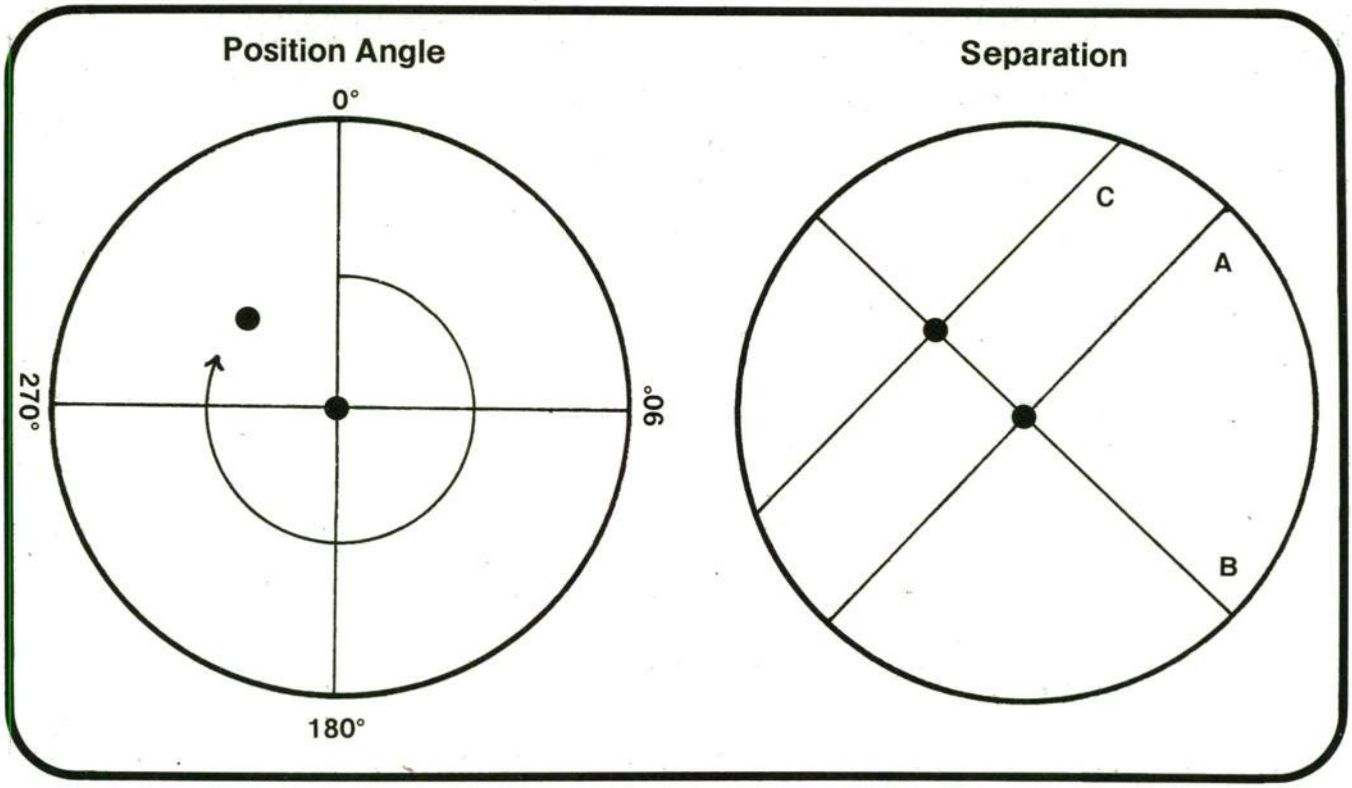
by
James Mullaney

A century ago the measurement of visual double and multiple stars was of high priority to both the professional astronomer and the serious amateur — men such as the Herschels, the Struves, Aitken, Dawes and many others. Today, however, only a handful of observers remain active in this important field. Their task of watching over the more than 65,000 pairs that have been catalogued is hopeless — yet one that brings with it a unique opportunity for the well-equipped observer to work side by side with the professional astronomer!

ASTRONOMY's monthly Star Dome department can serve as a good introduction to the pleasures of casual double star observation (one or two are described in detail every month). Literally thousands of these colorful gems of the heavens lie within reach of even the smallest telescope, and no two are exactly alike in appearance! A seemingly endless variety of tints, magnitudes and component configurations greets the stargazer in a delightful celestial pageant.

An informal survey of the sky's showpiece double and multiple stars might generate your desire to become more deeply involved in this field. Areas in which you may want to work include color studies, or a revision of Dawes' famous empirical limit for resolution. There's also the possibility that you might discover an occasional new pair — either one that's been missed in the grand surveys of the past, or (more often) a previously unresolved duo whose orbit has "opened up" over the years.

The most valuable contribution you could make to this field would be the routine measurement of selected pairs from among the multitude already discovered — generally close, rapid moving binaries at important phases of their orbits. Such measures involve *determination of two* basic parameters essential for orbit studies by the professional astronomer.



The two important measures to be taken in double star work are position angle and separation. Position angle is the orientation of a companion star with respect to its primary; in the diagram at left, the companion has a position angle of about 315 degrees. At right, separation is measured with a filar micrometer. The two fixed wires or webs A and B intersect the primary, while B also bisects the companion; the movable web C runs parallel to A, and when C crosses the companion star, the separation in seconds of arc between A and C equals the double's separation.

One of these is the *position angle* of the double; this is the angle of the companion with respect to the primary (always the brightest member of the system). Position angle can be thought of as a stellar compass heading as seen through the eyepiece of a telescope. More exactly, it is a measure of the relative position of a pair in polar coordinates.

Position angle is defined as north in the sky being 0 degrees; east, 90 degrees; south, 180 degrees; west, 270 degrees, and finally back to north again as 0 degrees. In a normal inverted telescopic view, north is at the bottom of the field and east to the right when facing south. (Note that a star diagonal, often used for convenience with a refractor or catadioptric telescope, gives a mirror image: North and south are erect, but east and west are still inverted. Such devices cannot, therefore, be used for double star measurement, explaining why most observers in this field have very stiff necks at the end of a night's work!) To be of value in orbit studies, the position angle of a double star must be measured to an accuracy of at least 0.5 degree, and preferably to 0.1 degree.

The second essential parameter to be measured is the *apparent angular separation* of the components in the sky in seconds of arc. Remember that one degree is divided into 60 minutes of arc, and that each minute is further subdivided into 60 seconds of arc. Our moon, which spans 1/2 degree in the sky, therefore covers 30 minutes or 1,800 seconds. One second of arc is a very small angle indeed — yet double star separations must be determined to 0.1 second or better to be of any use!

Since the periods of most of the close binaries visible in small instruments span many decades and often centuries, changes in position angle and separation are generally quite slow. However, at certain phases in their orbits — *periastron* (closest approach of the components), for example — such changes can become quite rapid. The bright double star Castor (in Gemini) is one such case. Now opening from a minimum separation of 1.9 seconds in 1969, the changing gap between the stars is apparent to an attentive observer from season to season even without measurement. Perhaps more dramatic is the change in position angle exhibited by many pairs near periastron. The companion of the well-known binary Gamma Virginis whips along at more than 70 degrees per year at such times! Both of these objects are presently within easy reach of a three inch refractor, but at closest approach their suns merge into blended elliptical blobs with rotating major axes — presenting a challenge of cosmic proportions to the double star measurer.

Many devices have been perfected over the years for measuring visual double stars, among which are the ring, crossbar and double image micrometers, and the eyepiece interferometer. The traditional tool, however, for such work is the filar (more accurately, the bifilar or two wire) micrometer. This is probably the most useful and versatile of all available instruments.

The filar micrometer is essentially a housing containing two very fine wires or webs, generally with one fixed in position and the other movable by means of a precision, fine thread screw having a calibrated dial or drum head. You can measure the angular separation of a double star by carefully centering the primary on the fixed wire and turning the drum head until the movable wire exactly bisects the companion. Several readings should be made in succession and a mean taken as the separation for that date. Measures should be repeated over a number of nights in a given season, to reduce possible instrumental and observational errors.

The micrometer also contains an accurately graduated degree circle with indicator, which reads the position angle of a pair when the fixed wire is bisecting both stars at the same time. The circle, drum head and wires are usually provided with some form of variable intensity illumination for visibility in the dark. A drawtube in the micrometer's base fits into the standard size (1-1/4 inch) focuser used on most instruments, its high power eyepiece serving as that for the telescope itself.

The small eyepiece micrometers that are often used on microscopes for measuring specimens need only the addition of a position angle circle and indicator to be modified for double star work. Although most have microscope size (.917 inch) drawtubes, adapters can be made or purchased at nominal cost to fit them into standard eyepiece holders.

Filar micrometers were often supplied as a standard accessory on professionally made telescopes in the past; even today, they are occasionally offered on the astronomical market. Frequently a micrometer can be found sitting idle in the instrument room of a high school or college observatory, waiting to be put into useful service by some dedicated observer.

The requirements of a telescope intended for serious double star work are few, but demanding. It must have a sturdy, well-aligned equatorial mounting with a good clock drive, since measurements must be made at the highest magnifications the atmosphere will allow (often 100 power or more per inch of aperture). Bisection of close star images is simply impossible if drifting and shaking of the telescope interferes.

The smallest aperture with which useful work can be undertaken is somewhere around five or six inches for refractors and catadioptric telescopes, and perhaps eight inches for conventional Newtonian reflectors. The difference here is simply a matter of design focal ratios; long focal lengths (with their greater image scales) are preferred over short ones for double star measures. Needless to say, optical quality should be the best that can be had for such demanding observations near the resolution threshold of the telescope.

Double star measurements made with the new breed of compound catadioptric telescopes that are widely used by observers today should be of special interest. These instruments were nonexistent back in the heyday of such work, and little is known about their resolution capabilities in this field. Does Dawes' limit hold true for a modern Maksutov or Schmidt-Cassegrain system? Can such instruments make useful measures of tight binaries significantly below this limit — as some observers suspect?

Regarding sky conditions, the main need is for good seeing (image steadiness) rather than high transparency. Hazy, muggy nights that are useless for other types of deep sky work are often superb for double star measurement. Stagnant air indicates a tranquil atmosphere (a condition common in the eastern part of the country, especially during summer months).

The raw measures of double stars obtained at the telescope generally require some simple mathematical reductions before they can be used for orbit determinations. The procedures are interesting and easily undertaken, especially with modern pocket calculators. Once reduced, such measures can be considered as the finished product of the observing program and submitted to experts for analysis. After accumulating data over a period of years, you may wish to plot your own orbits as well, and a number of elegant geometrical and analytical methods are available for the purpose. Clearly, the sky is the limit in visual double star work!

As for you, the observer, you must have reasonably good eyesight and a trained eye as well (which comes automatically with regular use of your telescope). Perhaps more important, you must be patient and philosophical about the work you're undertaking. Your labors at the eyepiece will likely not bear fruit for generations to come — and yet there is definite satisfaction in knowing that something of value can be accomplished for the future of astronomy.

As Dr. Charles Worley so well put it, "... a double star measurement made with care has permanent value. If binaries in critical phases of their orbits are not observed, in many cases we may have to wait hundreds of thousands of years before the same stages recur ... there is at present room for the serious amateur to make a definite contribution in this field, just as he has in the past."

Surely the seasoned, well-equipped astronomy enthusiast who is seeking fresh challenges and new frontiers among the stars would do well to consider the measurement of neglected binary systems. This is an endeavor worthy of your attention, and full of opportunity for useful work. Should enough of your fellow observers be persuaded to enter this field, perhaps a society of visual double and multiple star observers could be formed. The need clearly exists for such a movement — one that would already possess a proud heritage from the past and hold great promise for the future.

Above all, remember: The stars will not stand still!

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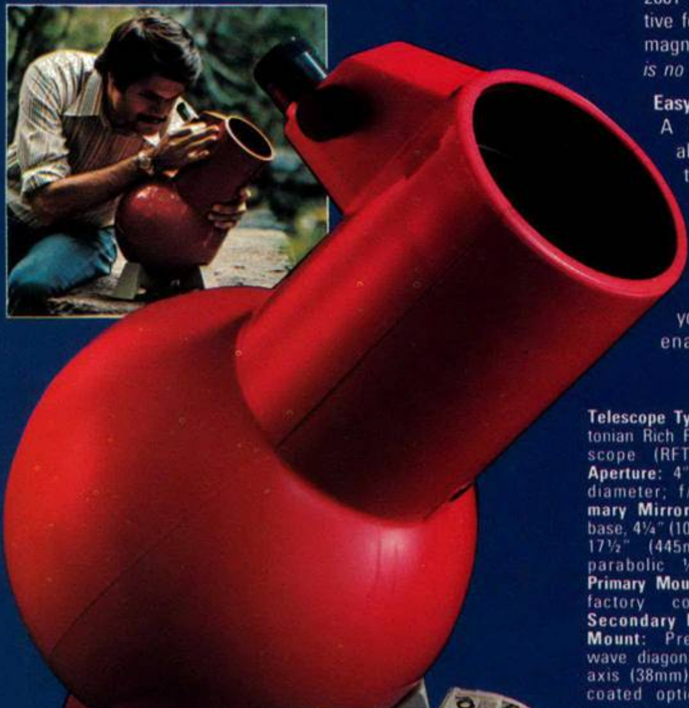

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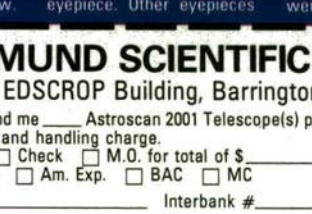

Telescope Type: Newtonian Rich Field Telescope (RFT). **Clear Aperture:** 4" (102mm) diameter; f/4.4. **Primary Mirror:** Pyrex® base, 4¼" (108mm) dia. 17½" (445mm) F.L. parabolic ⅛ wave. **Primary Mount:** Fixed, factory collimated. **Secondary Mirror & Mount:** Pre-aligned ⅛ wave diagonal 1½" minor axis (38mm) mounted to coated optical window. **Eyepiece:** 1¼" O.D., 28mm F.L. compound Achromatic. **Power:** 16X with above eyepiece. Other eyepieces or optional Barlow lens may be used to increase power. **Field of View:** 3.0° with eyepiece supplied. **Focusing:** Smooth, posi-grip, rubber roller focusing (25 feet to infinity). **Telescope Body:** Special, high-impact plastic. **Dimensions:** Length: 17" (432mm); Sphere dia.: 10" (254mm). **Weight:** 8.4 lbs. (3.8kg) without stand. Stand weight 2 lbs. (0.9kg).

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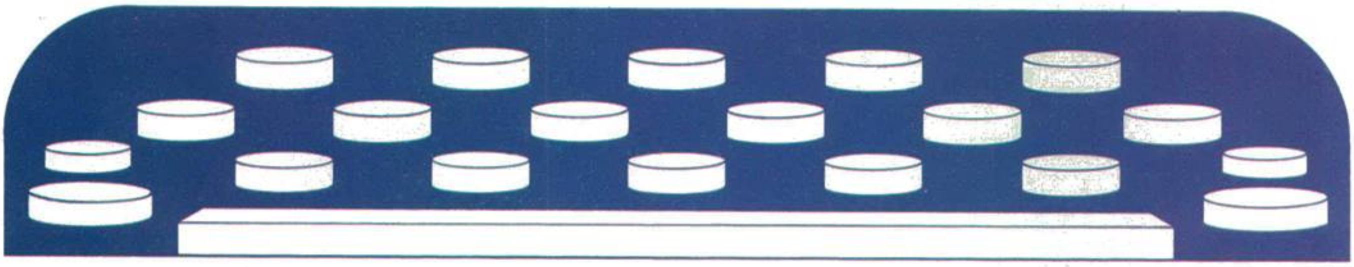

IN FOCUS

Ooops!

Here are a few errors that have appeared in recent issues:

April 1977, page 39 — author Alan Witzgall and editor Richard Berry, with more than 20 mirrors ground between them, forgot to stress the need to fine grind your telescope mirror (first with the mirror on the top, and then on the bottom) with alternate wets of abrasive. If you grind every wet with your mirror on top, the focal length of the mirror will come out 10 to 12 inches too short!

September, 1977, page 9 — a phrase was omitted. The sentence should read, "The next stop on our reconnaissance would be Barnard's star, whose mass is unmeasured but is probably about 0.2 solar masses, and its astrometrically detected, unseen companion with a mass about twice that of Jupiter." Also note three more incorrect figures: The mass of the star +36°2147B is 0.20 rather than 0.02 solar masses, and the components of L 726-8 should be 0.44 and 0.35 solar masses, rather than 0.044 and 0.035 solar masses.

September 1977, page 46 — the three photographs were incorrectly credited to Bill Iburg; the astrophotographer was actually Walter Hamler. Our apologies to both gentlemen.

September 1977, pages 48 and 49 — in the boxed article, "Polar Alignment for Photography" by Brad Wallis and Robert Provin, the same error cropped up twice. The last line in the first column should read, ". . . declination drift to less than one second of arc in 20. . ." In the third column, the 10th line from the end of the article (above the summary) should read, ". . . drift down to one second of arc per 30 minutes of. . ."

Sir / One way to deal with light pollution is to meet it head-on by observing in the daytime! With good alignment of your scope and good setting circles, together with correct planet positions and sidereal time, objects fainter than second magnitude can be found and companions of doubles (Mizar, for example) can be seen at fourth magnitude. Some of the finest seeing occurs just after sunset. Filters, especially the polarizing type, are very helpful. Mercury and Venus are seen at their best when high in the morning sky. And the sun itself is a very interesting object, especially with the new types of filters. Fascinating — but expensive — are the new solar prominence viewers. Naturally my permanent telescope and dome are a great help (especially in the daytime), but for a long time I used smaller scopes on a tripod with an umbrella for shade.

WALTER F. TAYLOR
Fresno, Calif.

Sir / Just a quick note thanking you for another fine issue of ASTRONOMY. The September issue just has to be the best one yet. It confirms my wisdom in renewing my subscription for another four years. Keep up the good work!

The article about light pollution on page 26 was especially interesting, and reminded me of a camping trip I made to Michigan's Keweenau Peninsula (which juts far up into Lake Superior). I awoke in the night and saw a bright band of light above me. It took a moment for me to realize I was looking at the Milky Way. The stars shone with a fierce intensity. If only every person could experience that! It was a sobering revelation of the degradation of our atmosphere in urban areas. However, perhaps there is a glimmer of hope in the energy crisis and total black-outs experienced recently in New York. When Americans everywhere stop their prodigal outpouring of photons (by necessity or emergency), perhaps we can all breathe a bit easier.

ROBERT J. JACKSON
Grand Haven, Mich.

Sir / After reading the September issue, with the article on light pollution by Richard Berry, and the letters by J.M. Buehring, David Godin, David Healy and Rick Kurczewski, I felt impelled to state another view of the situation. I am a practicing physician with a strong interest in astronomy and astrophysics. I am also a rare bird (judging from your past comments on the subject) — a woman who subscribes to ASTRONOMY! I have two children under the age of three and I live in the East Coast Megalopolis.

I have great sympathy for those who wish to see the Milky Way, but I have bright porch and garage lights. I, too, would like to view the stars in their great glory, but I am not prepared to pay the price — which is an increased risk of assault and rape, with the attendant pain and risk of pregnancy and disease. I must also attempt to protect myself and my family from the increasing number of house break-ins and burglaries. And finally, there is the more mundane matter of not hitting solid objects or persons with the car at night. If there is anyone who thinks these are not real problems, I invite him to spend an evening at his local hospital emergency room. In short, to quote Berry, I am one of the many who "like lots of lights — usually for security", and I am very hard to convince otherwise! Given the dangers of our society, perhaps Kurczewski's island (where all lights except red-covered flashlights would be banned) is a better idea than turning out all the outside lighting around our homes.

HELEN L. DUNSFORD, M.D.
Milford, Conn.

Dr. Dunsford / The suggestion made in the article, and supported by most people dealing with light pollution, is not to turn lights off, but to use efficient lights that don't illuminate the night sky. Light pollution is all wasted light — misdirected *light that isn't stopping crime. Proper shielding of lights means lighting the ground efficiently rather than throwing light in all directions. Why not try installing an aluminum reflector over your porch and garage lights so that the half of the light now wasted in the sky is efficiently directed to your security areas?*

Sir / Without a doubt, "Slow Boat to Centauri" (August 1977) was the most enjoyable, fascinating, and beautifully illustrated article that I have ever read, in your or any other astronomical magazine.

If Thomas R. Schroeder ever grows tired of writing — which I hope he doesn't — he will always have his superb painting talent to fall back on.

Even though interstellar travel will most likely never take place in our lifetime, ASTRONOMY and Schroeder sure make it fun to dream.

GUY M. MORLEY
Salem, Ore.

Sir / My thoughts on buying and using binoculars differ considerably from those of Robert Ariail (In Focus, August 1977).

To search department stores in the hope of finding binoculars that will perform well and endure is hopeless. Department store binoculars are of poor quality; they are designed to be made cheaply, have a nice outward appearance, and sell at a price the general public is willing to pay.

The stores' cost in stocking these plate-glass prism binoculars is low, and their profit margin high. There is no possible way a "department store" type could perform as well (or nearly as well) as the top quality Zeiss or Leitz. There is no reason to throw money away on "department store" type binoculars.

Quality binoculars, such as Bausch & Lomb and Bushnell customs, perform very well. A quality 7x50 or 7x35 easily outperforms a cheap 80mm product. If you can afford them, Zeiss or Leitz binoculars are no doubt the best and most desirable, but Bausch & Lomb 7x50s can be purchased for less than $150 and leave little to be desired optically or mechanically. Their 46-ounce weight makes a tripod necessary for stargazing. Where light pollution is a problem, the 22 ounce 7x35s will perform as well and need no tripod. Also, Leitz makes 7x42 roof prism binoculars that weigh only 23 ounces.

MICHAEL WILLIAMS
Tampa, Fla.

Sir / I am interested in obtaining slides of our solar system, the Andromeda galaxy, Orion nebula, and other astronomical subjects. Where can I obtain them at reasonable cost?

HERBERT PEREZ
Hyattsville, Md.

Mr. Perez / Your request for information is one of those most frequently received by the editors of ASTRONOMY. Many firms, including several who advertise in our pages, offer slides of astronomical subjects. Among the best sources for such photos, of course, are the observatories themselves who originally took them. The following is but the beginning of a nonexhaustive list of observatories with prints and slides available to the public.

Hale Observatories
c/o California Institute of Technology Bookstore
1201 E. California Blvd.
Pasadena, CA 91109

Catalog — Public Information Office
Kitt Peak National Observatory
P.O. Box 26625
Tucson, AZ 85726

Lick Observatory
University of California
Santa Cruz, CA 95060

Photographic Service Dept.
Yerkes Observatory
Williams Bay, WI 53191

You can write to any of these institutions for information or for their catalogs (some for a small fee). Prices for the slides will differ from one observatory to another.

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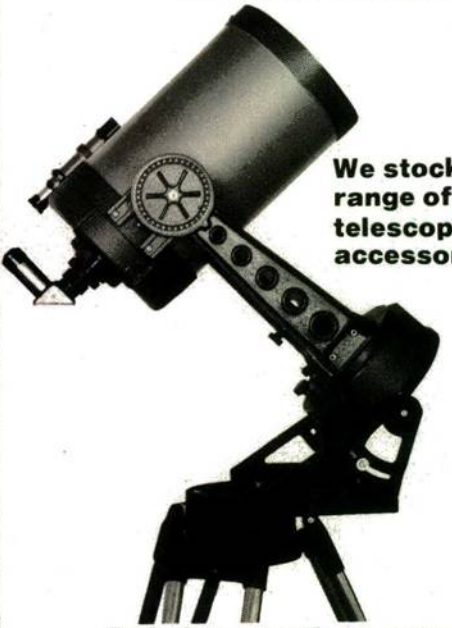

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PHOTOGRAPHY IN ASTRONOMY

Improving Your Lunar Photographs

by
Lee S. Najman

The most important technical key to a good print is a good negative: A good negative will easily produce a good print, but a bad negative will always be difficult to print satisfactorily! Although proper film exposure is one requirement for good negatives, it's not easy to attain with a subject of extreme contrast like the moon. Often during the crescent and quarter phases of the moon, the brightness difference between the shadowy terminator and bright limb exceeds the ability of the film (or photographic paper) to reproduce it accurately. What can you do then?

The trick to photographing a high contrast subject is to *reduce* the relative limb-terminator contrast so that they will both print using the same enlarger exposure. You'll then eliminate the need for burning-in and dodging, and your negatives will produce better prints.

Underdevelop for Low Contrast

What you need is a low contrast, flat negative. Developers like D-76, D-19 and Microdol are not low contrast developers, but you can reduce the contrast of the negative if you *overexpose* and *underdevelop* the film. Since the shadowy areas of a negative develop first (and faster than the denser areas), after an initial period in the developer, the only portion of the negative which continues developing quickly is the dense area. If you stop development right after the shadows have been developed and before the density of the highlights is fully built up, the contrast will be reduced. A very general rule is:

overexpose by 1 stop — underdevelop 20%
overexpose by 2 stops — underdevelop 40%.

We must emphasize that this is a very general rule, but it's a good starting point for your own experimentation. Remember: The whole roll of film must be handled in the same manner.

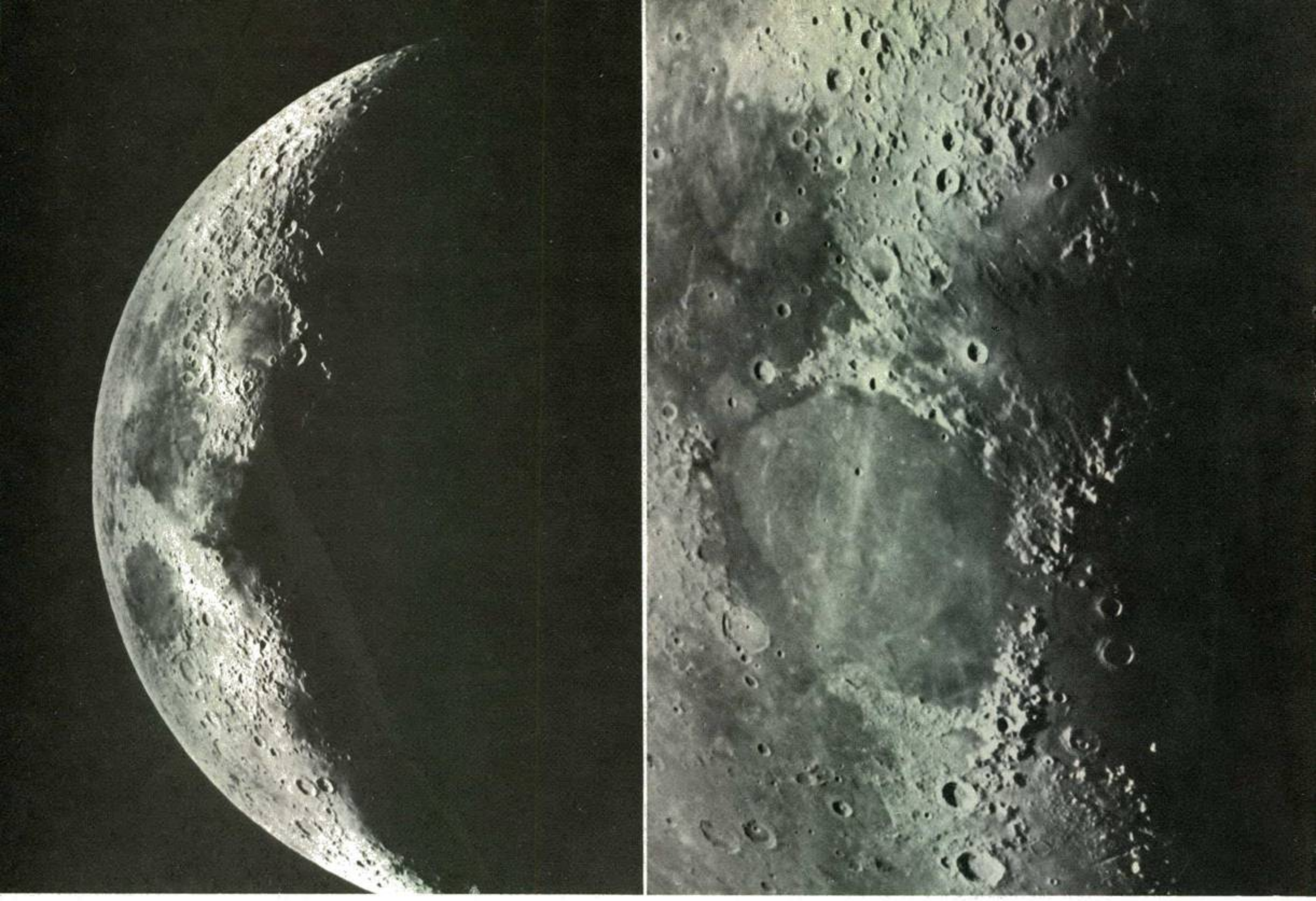
Compensating Developers

What if this additional technique still does not sufficiently reduce the contrast to give satisfactory results? One answer is to use a compensating type developer. The chemical action of a developer is normally directly proportional to the exposure the film originally received; hence, the greater the exposure, the more vigorous the developing action. This yields high contrast negatives from a high contrast subject. The lunar limb, being very bright, darkens the negative much more than the terminator. Typical high activity developers (like D-76) will continue developing the limb areas (increasing their density) far beyond that of the terminator, and will produce a difficult negative.

But if you use a compensating type developer, something else happens. Compensating type developers are used greatly diluted. Because of this dilution, the bright exposure portion (limb) rapidly "exhausts" the developer while the low exposure portion (terminator) continues to develop. This reduction of density in the high exposure portion, with a corresponding increase in density in the low exposure portion, results in an evenly toned negative. It's a snap to print such a negative, because all details and tonal ranges are recorded in one single operation.

You can make a compensating developer from commercially available Agfa Rodinal by simply diluting it more than normal. For developing Kodak High Contrast Copy Film, use Rodinol diluted 1 to 150. Mix 1.5ml of developer to 235ml of water to

The extreme brightness range between the lunar limb and terminator cannot usually be captured on film — and then printed without dodging and burning-in — without using a low contrast or compensating developer. This picture was taken on High Contrast Copy Film (a slow, fine grained emulsion), and developed in an extremely dilute compensating developer, Agfa's Rodinal diluted 1 to 150. The exposure was 1/4 second at the Newtonian focus of a 12 inch f/6 reflector. Photograph by Lee S. Najman.



For negatives already developed, local reduction of dense areas can be a real lifesaver! As originally developed, these negatives proved too extreme to print without extensive manipulation. After using Farmer's Reducer to bleach the bright regions away from the terminator, both negatives could be printed "straight" on medium contrast papers. Both pictures were taken at the Newtonian focus of a 12 inch f/6 reflector; the photo on the right has been highly enlarged. Photographs by Lee S. Najman.

make 236.5ml (eight ounces) of working solution. Develop the film for 18 minutes at 70 degrees Fahrenheit (21 degrees Centigrade) using a two second agitation every six minutes. The infrequent agitation prevents fresh developer from acting on the brighter areas. Stop, fix and wash normally. You'll be able to print on grades 3 and 4 paper *without* burning-in or dodging. This developer will work similarly with many other films.

Local Negative Reduction: The Last Resort

Negative reduction is a standard technique practiced daily by photographers. Basically, an overdense negative is dunked in a solution of "Farmer's Reducer" — a Kodak chemical which dissolves some of the silver in the negative, thus reducing the density. This is fine if you are trying to reduce the density of both shadows and highlights simultaneously — but you only want to reduce the highlights (dense areas), leaving the shadows untouched. Select a sharp negative, well-exposed in the shadow areas (maria are the best), and locally apply the reducing agent *only* to the overdarkened portions of the film until the density of the highlights approximates that of the shadows. This is considerably easier to do than it may seem.

Kodak recommends (instructions are packaged with the product) a dilution of 1 to 10 before using it on a well-soaked negative. Use fine retouching brushes and gingerly apply the solution to the *emulsion side* of the negative. You'll find that the action of the reducing agent starts slowly, but accelerates rapidly; it's easy to overreduce unless you're careful. Wash the negative with water every 30 seconds or so to retard the reducing action and inspect your work frequently. Stop reduction before you reach the level of the shadow areas, as reduction continues somewhat during washing. After washing, fix in a hardening fixer, dry and print normally.

You should try to keep the reducing solution from wetting the shadow areas (the terminator) of the lunar negative during this process, because the reducing agent could completely erase the already relatively faint shadow image!

Practice with rejected negatives before trying it on a valuable one. It takes only about 10 minutes to convert a nearly unprintable negative into one that can yield satisfactory prints with full tonal range and detail.

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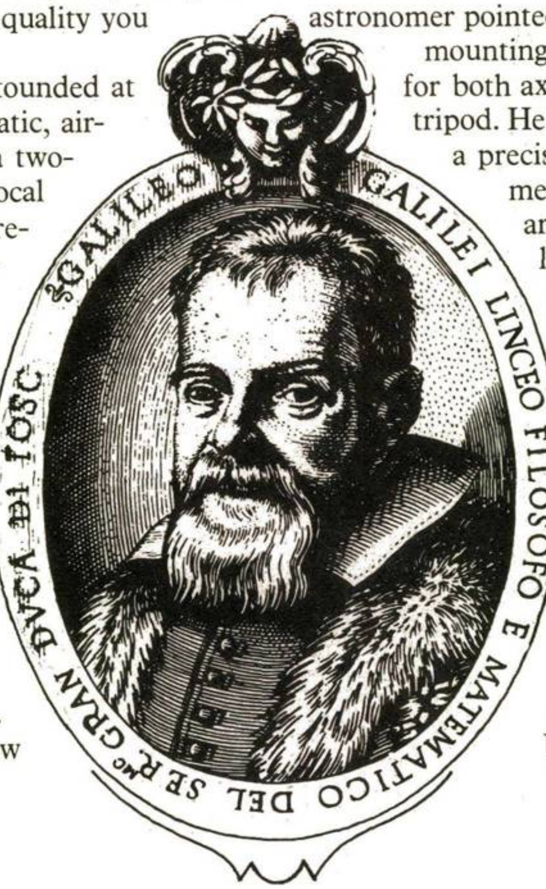
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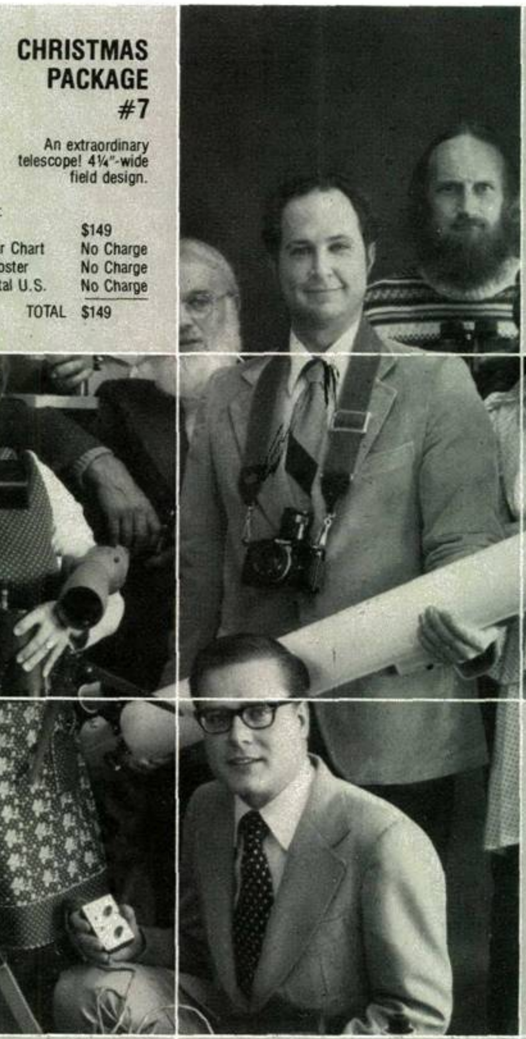

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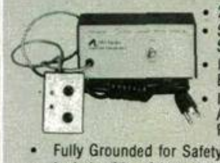

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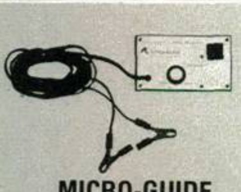

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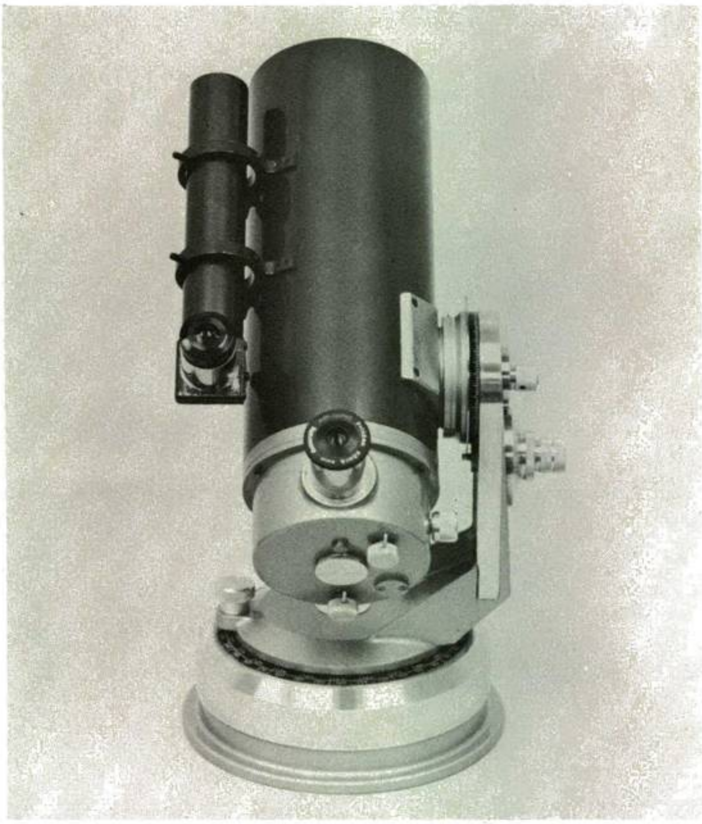

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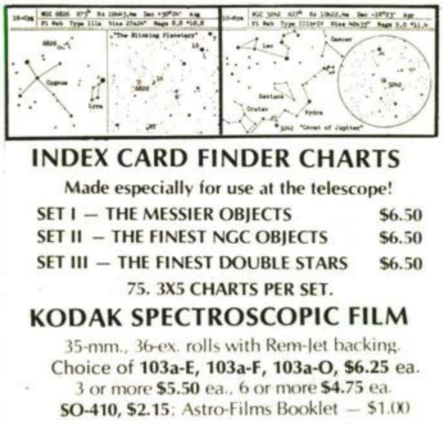

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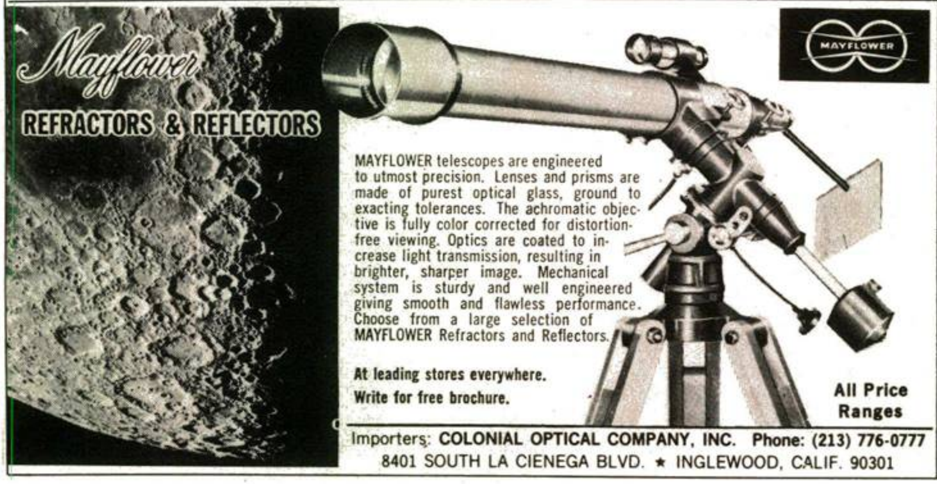

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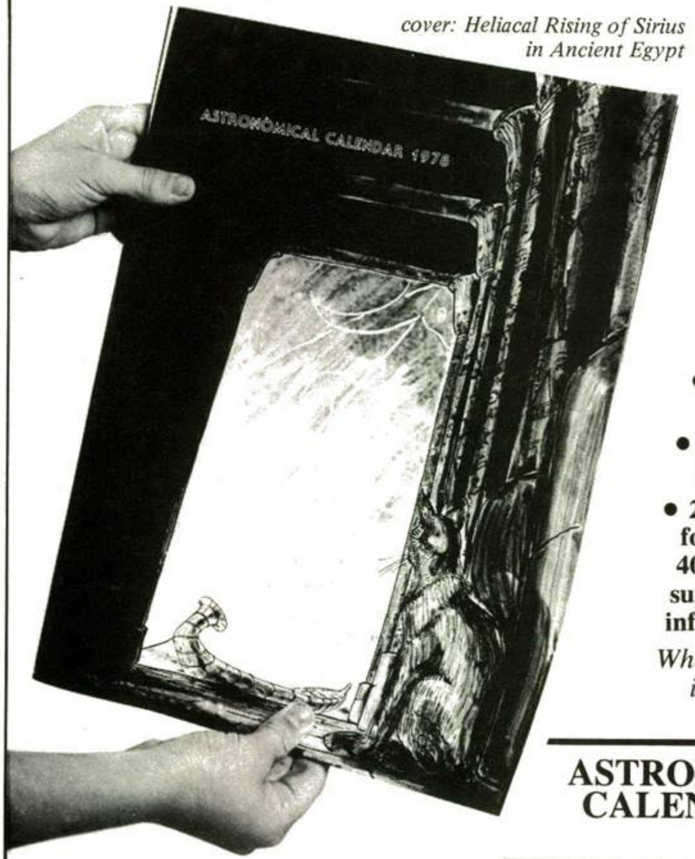

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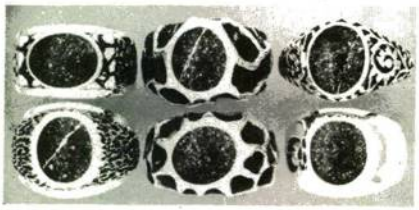

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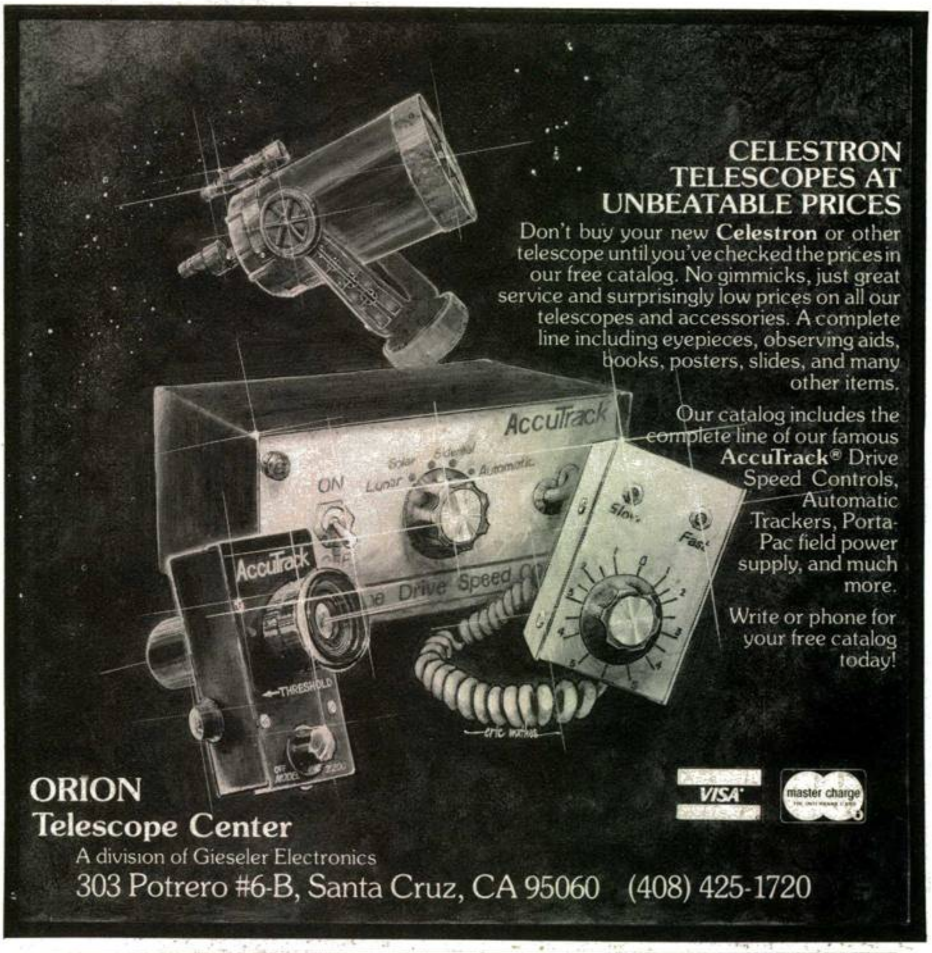

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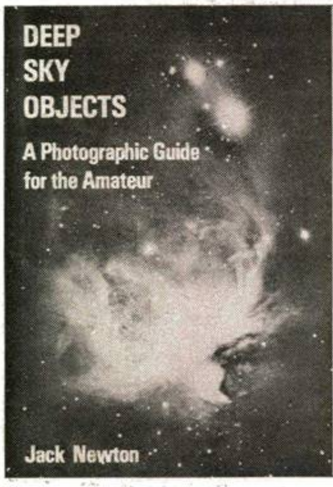

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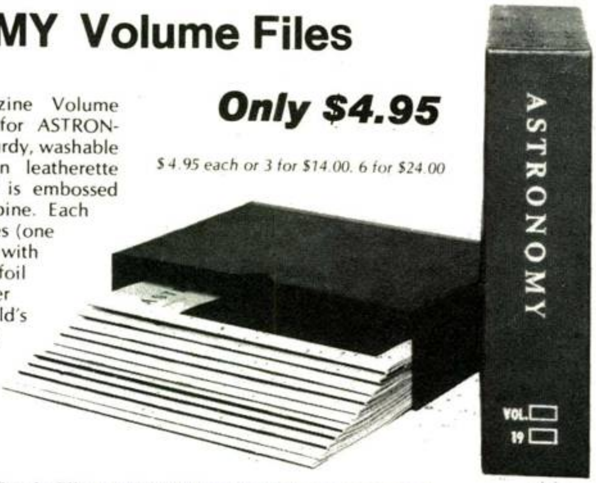

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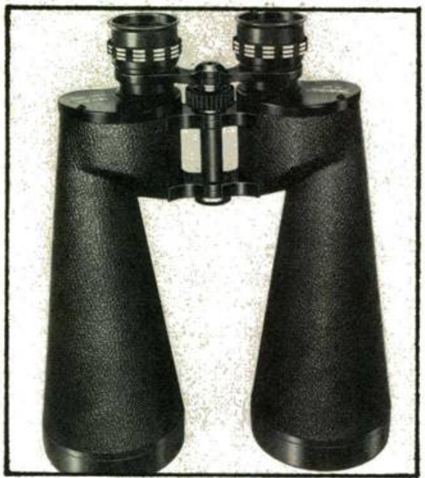

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WANTED — Slides from "2001", "Star Trek" "Star Wars", etc. Also newspaper reviews of "Star Wars". Send list, prices to Jim Martin Jr., 2300 Windsor Rd., Alexandria, VA 22307.

WANTED — Progressive new astronomy group desperately needs persons interested in sharing both financial costs and scientific rewards of operating an observatory in central Indiana (Indianapolis area) with a 12-1/2" Newtonian. Call Ronald F. Nye, c/o Schneider Engineering Corp. Phone (317) 898-8282 days.

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Scientists Discuss Possibility of Organisms in Jovian Atmosphere

Balloonlike organisms floating in the clouds of Jupiter may grow large enough to be visible to the cameras of Voyagers 1 and 2, according to Carl Sagan and astrophysicist E.E. Salpeter.

Sagan and Salpeter conducted detailed studies of Jupiter's atmosphere, comparing its ecology with that of Earth's seas. On Earth, simple photosynthetic plankton can be found at the upper level; fish which feed off the plankton are at lower levels, and marine predators which in turn hunt the fish. Hypothetical equivalents in Jupiter's atmosphere have been named sinkers, floaters and hunters.

The sinkers will drift downward from the level of the visible clouds into the deeper atmosphere of Jupiter, and will eventually be burned up by the planet's internal heat. Before then, they must have reproduced in order to maintain a steady state population.

As the sinkers drift downward, they will provide food that is "mopped up" by the floaters. Organisms that can propel themselves around to coalesce with other bodies in the clouds of Jupiter are the hunters. The approach and coalescence of two organisms to exchange genetic material serves the same function as mating. Some highly evolved Jovian organisms may include aspects of sinking, floating and hunting in their life cycles.

The hunters, or "gas bags", would move around by pumping out helium. The largest floaters and hunters in the clouds of Jupiter could grow to be many kilometers across, within the resolution of the Voyager probes' cameras.

Laboratory experiments have shown that large amounts of organic molecules can easily be produced from Jupiter's atmosphere. It contains many of the same gases as did the atmosphere of Earth, from which life first formed. The problem, though, is to explain what causes the red coloration so frequently seen on the planet.

Sagan and Salpeter found that simple production of molecules by the direct action of light does not seem to provide adequate supplies of red colored molecules at the right levels in the atmosphere, below the white ammonia clouds. Instead, they claim that the red coloration can come only as a result of biological action by Jovian organisms capable of photosynthesis — like simple algae on Earth. In other words, they claim the red colors in the clouds are visible evidence of life on Jupiter, and that Jovian organisms are red in color. The red spot could, therefore, be particularly favored for life.

Voyagers 1 and 2 will not enter the Jovian atmosphere. An orbiter/entry mission has been planned, however, for 1982. Carrying a sensitive mass spectrometer, such a probe could detect the organic molecule levels hypothesized by Sagan and Salpeter.

Instead, Voyagers 1 and 2 will photograph Jupiter as they fly past before proceeding on to Saturn. The similarity of Saturn to Jupiter leads Sagan and Salpeter to propose possible airborne organisms in the clouds there, also.

They do not, however, speculate on how such life could have arisen in the first place.

Is Massive Black Hole At Center of Milky Way?

New observations by radio astronomers indicate that there may be a supermassive black hole at the center of our galaxy.

A team from the National Radio Astronomy Observatory (Green Bank) used their 140 foot (43m) dish in a nationwide hookup with NASA's 208 foot (64m) Goldstone (Calif.) aerial and the 120 foot (37m) Haystack antenna near Westford, Mass., to form a Very Long Baseline Interferometer (VLBI) with which they observed the galactic center at 4cm wavelength. This area is a radio source known as Sgr A West, and also coincides with an infrared hot spot.

The Green Bank team, lead by K.I. Kellerman, found that 25 percent of the source's radio emission comes from a core only 10 astronomical units across (one astronomical unit is approximately 93,000,000 miles — the distance from Earth to the sun). The rest comes from a "halo" of approximately 200 astronomical units in diameter. Over a six month period, they found no detectable expansion or contraction of the source.

The radio luminosity of the galactic center source is 10^{33} erg/second which, they say, is 10,000 to 10 million million times less than the radio nuclei in other spirals and ellipticals or in radio galaxies and quasars.

The Green Bank group, in an article in the **Astrophysical Journal Letters**, noted that the source could be a supernova, pulsar, or other stellar object, because it lies at the position of highest stellar density in the galaxy. But theorists including Donald Lynden-Bell of England, they said, have proposed detection of such a tiny radio source as a test on the existence of a black hole at the galactic center. The size of the radio source observed by the VLBI corresponds to the diameter of a black hole of 100 million solar masses — close to the suggested upper limit of such an object.

Past Asteroid Bombardment May Have Aided Evolution

Does man owe his evolutionary existence to a barrage of huge asteroids that struck Earth, the moon and the other inner planets in the solar system some four billion years ago? Are modern ocean basins the product of giant impact craters that formed early in the history of our planet? If so, what are the consequences for life elsewhere in the universe?

These questions were raised in a recent meeting in Washington of the American Geophysical Union by Dr. Herbert Frey, a NASA-University of Maryland scientist working at NASA's Goddard Space Flight Center in Greenbelt, Md.

Information returned from Apollo lunar landings and photographic evidence from spacecraft studies of the moon, Mercury and Mars seem to show that all these planets experienced an intense bombardment by asteroids, 30 miles (50km) or more in diameter, four billion years ago. This catastrophic cratering must also have affected the early Earth.

Building on the work of other scientists — including studies of crustal evolution by Goddard's Dr. Paul Lowman — Frey suggested this early destructive bombardment may be responsible for the first ocean basins formed on Earth. Giant impacts would trigger subsurface melting, leading to vast outpourings of lava that would flood the huge craters caused by the impacts.

Frey further suggested that these conditions made possible a very early beginning of plate tectonics, in which large rigid crustal blocks shift position on Earth's surface. Such movements are the cause of earthquakes and volcanic eruptions today.

Formation of these basins flooded by basaltic lavas is necessary for plate motion to occur. According to Frey, "crustal uplift and rifting were probably initiated in the thinned crust of Earth's mare basins. Loading of these basin margins by sediments encouraged subduction, which initially was probably confined to the continent-ocean (highland-mare) interface. With subduction (sinking of crustal plates) established, seafloor spreading at midmare ridges could begin the long process of oceanic crustal reworking which, after several cycles, would eventually generate the young oceanic crust of the modern plate tectonics period."

Four billion years ago Earth would have looked much like the moon does today. The moon never had plate tectonic motions because it cooled too rapidly.

Frey thinks evolution of life on Earth would have been very different from what it has been had there been no asteroidal bombardment. For example, Earth might well have been covered with a global ocean, with no continents and no islands — nothing but water; or, it might have been mostly dry land, with only a few patches of water here and there.

In either case, evolution of life would have been far different because the environment would have been radically different from that which we know has existed over eons. Frey believes it is likely that many of the higher life forms, including man, would not have evolved.

Origin of continents and ocean basins has long been a problem in geological research. The most likely explanation is asteroidal bombardment, according to Frey. "It is obvious that the moon, Mercury and Mars were struck by hundreds of huge objects approximately four billion years ago. There is no way Earth could have escaped such a pounding as well. My calculations show that more than 50 percent of Earth's original crust would have been converted into ocean basin topography based on the number, diameter and depth of the observed lunar basins," he said.

If asteroidal bombardment is responsible for the original ocean basins of Earth, then intelligent life elsewhere in the universe may also depend on such a catastrophic event. "There is no reason to believe that similar events would have occurred in the same time frame on other Earthlike worlds in other star systems," Frey said. Timing of the bombardment is critical. If too early, they would impact molten crust and no traces would remain. If it happened much later, *after* life had formed, evolution would be seriously affected. Intelligent life forms might not have time to evolve.

Planets which suffered no asteroidal bombardment of this type would probably not have moving plates, as does Earth. The dense crust of the ocean floors is necessary for subduction. Without such sinking of the plates, only limited plate movement is possible.

Frey pictures the asteroid bombardment and its effect in this way:

After the formation of the planets 4-1/2 billion years ago, there was still a large amount of mass left over in the form of asteroids located throughout the solar system.

These objects had their paths changed by the gravitational force of the large planets, especially Jupiter. For reasons that are still not clear, a large number of these asteroids were deflected into the inner solar system about four billion years ago.

As a result, all the inner planets (Mercury, Venus, Earth and the moon, and Mars) were pounded by the 30-mile-diameter rocks. On Earth, such impacts produced gigantic craters (basins) more than 620 miles (1,000km) across and 8 to 12 miles (10 to 20km) deep. Over half of Earth's original crust became low basins; the rest remained as high standing continents.

Lava from below the fractured crater floors poured into the basin and flooded the low lying areas with basaltic material. These deep basins provided natural drains into which the water of Earth would collect.

Below the new ocean basins the molten Earth was moving, causing uplift of the basin floor. The floor rifted apart, and new lava welled up along the rift. The crack widened, and seafloor spreading pushed apart the newly formed plates on either side.

Near the edge of the basins, the greater weight of the basaltic lava crust sank below the continental edge as subduction responded to the pressure from the spreading ridge.

Are more giant asteroids still around in the solar system? And what are the chances that they will hit Earth?

"The best modern examples are the Apollo asteroids," said Frey, "which have orbits that cross the orbit of Earth. None of these are likely to hit Earth in the foreseeable future."

In Memory:

Stephen Walther's editorial contribution to Astronomy will never be forgotten.

Robert M. Edmund, President
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Boeing Selected to Build World's Largest Windmill

The largest windmill in history will be built over the next two years in a test program conducted by the Energy Research and Development Administration (ERDA) and managed by NASA.

NASA and ERDA are negotiating a contract with the Boeing Co. for about $10 million to design, build, assemble, install and test a nominal 2.5 megawatt (2,500 kilowatt) electrical generating system, with blades spanning 300 feet (91 meters) in diameter.

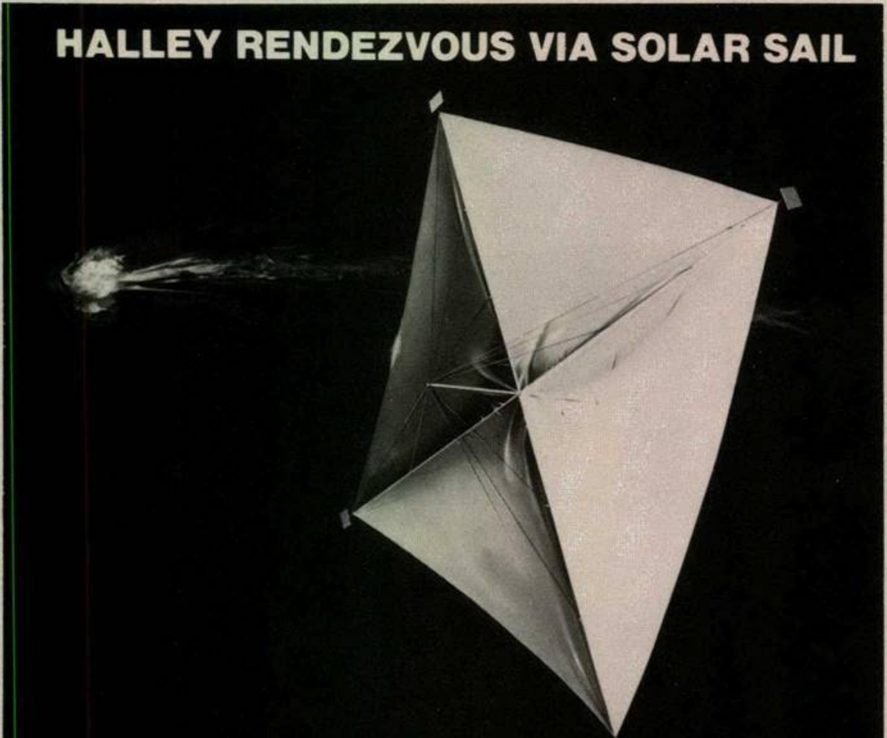
The large *wind turbine* (the name for modern electrical generating windmills) will be designed for sites with a mean wind speed of 14 m.p.h. (23 k.p.h.). Sites with such modest winds are relatively common throughout the United States. The wind turbine is scheduled to be built in late 1979 at a site to be selected by ERDA.

Although experimental, the system will be located at a utility company site and will supply electricity to the local electrical system for use by the general public. The purpose of the system is to investigate the economics and operating characteristics of large wind turbines when coupled to conventional power plants. This project will place special emphasis on developing a wind turbine capable, when produced in quantities of up to 100 units, of providing electricity at a cost approaching that of conventional power plants.

The experimental wind turbine is part of ERDA's program to develop wind energy systems and test their practicality as a potential source of energy. NASA's Lewis Research Center in Cleveland, with expertise in aerodynamics and structures, will direct this project for ERDA.

Research to date has indicated that the cost of energy from the wind turbine should decrease as the size of the machine increases.

ERDA is also investigating the development of small (up to 10 kilowatt) windmills that could be used by individual rural homes or farms, and is performing research and development on advanced unconventional windmills.



This version of the solar sail concept — the Yankee Clipper — is one of several alternative designs NASA is considering for a rendezvous with Halley's Comet in 1986. The sail, which is made of thin aluminized plastic, would be powered by the sun's energy for weeks or even months as the comet is studied. NASA photograph.

Possible Link Noted Between Galaxies and Barred Spirals

Ordinary spiral galaxies such as our own may have more in common with barred spirals than meets the eye, according to a new proposal by two astronomers at University College in the United Kingdom. The astronomers, Takuya Matsuda and Alistair Nelson, questioned why there should be a ring around the center of our galaxy that is remarkably free of interstellar gas and dust. The answer, they believe, is that this area is swept clean by a short bar of old, red stars, like a smaller version of the bar seen in a barred spiral galaxy. In a recent article in **Nature**, they termed the sweeping effect the "galactic vacuum cleaner".

Matsuda and Nelson said that there is a dense disk of gas and dust with a radius of about 2,000 light-years at the center of the galaxy. Around this is the area in which interstellar material is surprisingly scarce. Beyond about 6,500 light-years from the center of the galaxy out to our own distance of 30,000 light-years or so and beyond, the gas and dust is plentiful again.

The astronomers proposed that the gas-and-dust-free area is swept clean as the bar rotates. Interstellar material ahead of the bar is forced by shock waves to move toward the galaxy's center, while other material spirals outward from the ends of the bar to form the galaxy's curving arms. Such a vacuum cleaner effect is seen in genuine barred spiral galaxies.

Matsuda and Nelson said that even ordinary looking spirals may need a short bar at their centers to excite the spiral structure. In normal spirals, as in our own, the old, red stars of the bar are obscured by new, blue stars forming as the shock waves from the bar pass through the interstellar gas and dust. However, red light plates of spiral galaxies do reveal traces of such short central bars of old stars.

Matsuda and Nelson estimate that the proposed bar at the center of our galaxy has a mass less than 1/10 that of the galaxy as a whole — considerably less than the probable mass of the bar in a genuine barred spiral. Therefore outwardly, at least, our galaxy would still look like a conventional spiral such as the Andromeda galaxy (M-31).

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British Plan Millimeter Facility

Explosive development of new techniques in the past decade has enabled astronomers to open up almost every part of the electromagnetic spectrum to observation. The last remaining blind spot has been the millimeter waveband. Millimeter waves have wavelengths longer than infrared waves, and shorter wavelengths than radio. New developments seem likely to remove that blind spot in the near future.

Several teams of observers have been working in this band (from about 8mm to 0.8mm), but so far have only used instruments adapted from other purposes. Now the British Science Research Council (SRC) seems ready to follow its infrared telescope (now nearing completion in Hawaii — see Astro-News, February 1977) with the next logical development, a millimeter wave observational facility.

Over the past year and a half, an SRC steering committee has been planning the design of a proposed millimeter wave telescope. In March, project scientist Dr. R.E. Hills reported the outcome of these plans to a meeting of the royal Astronomical Society in London. The peculiar observing needs in this waveband can, it seems, best be solved by combining radio and optical techniques, together with the latest solid state detectors which make it worthwhile to consider the project.

The proposed instrument will be a dish about 50 feet (15 meters) across — substantially bigger than any optical telescope, but small by the standards of radio astronomy. At present, the design is for something much like a miniradio telescope, with the aluminum dish being allowed to bend under gravity as it tilts, but designed so that each deformation changes the shape only within a family of paraboloids. This homology principle is the same as has been successfully applied in the German 100 meter radio telescope. As long as the dish holds a parabolic shape of one form or another, it continues to function perfectly, with the position of the focus shifted slightly. For different elevations, the focus cage which contains the detector equipment is shifted. This is a simpler and cheaper task than building a rigid, but much more massive, nondeformable dish.

This radio type dish will be housed inside a larger version of a more-or-less conventional dome. The difference is that, because of the size of the instrument, the dome must have a side slit opening, which means much of the shielding effect of the dome will be lost. Hills said the SRC team has decided to cover the gap in the dome with a curtain of sailcloth backed with polythene, which is both wind resistant and transparent at millimeter wavelengths.

At first it may seem a paradox to open the dome and cover it with a curtain, but there is a reason. Other instruments now being planned incorporate conventional full radomes, and while these keep the wind and weather at bay, they also block out wavelengths below 3mm. So the United Kingdom's instrument would be almost unique in being able to observe down to 0.8 millimeters. The nearest equivalent instrument is a 33 foot (10 meter) dish currently in the test stage at CalTech.

Planned resolution of the instrument is 13 seconds of arc, with steering and pointing accuracy of about two seconds. Instruments of this kind would monitor the vast amount of cold material between stars, and in regions of star formation, which radiate at millimeter wavelengths. They would also provide new data about the dusty regions at the center of many active, explosive galaxies and radio sources.

The instrument will probably not be built in the UK. Like the nearby infrared band, millimeter observations need altitude and dry air — both of which are rather scarce in England. Hawaii may be selected as the site; the instrument would then be alongside its infrared companion and could be run by the same administrative setup The chief problem is that although the cost of the project is far from excessive at $6 million, the SRC's budget is presently strained even to maintain existing projects.

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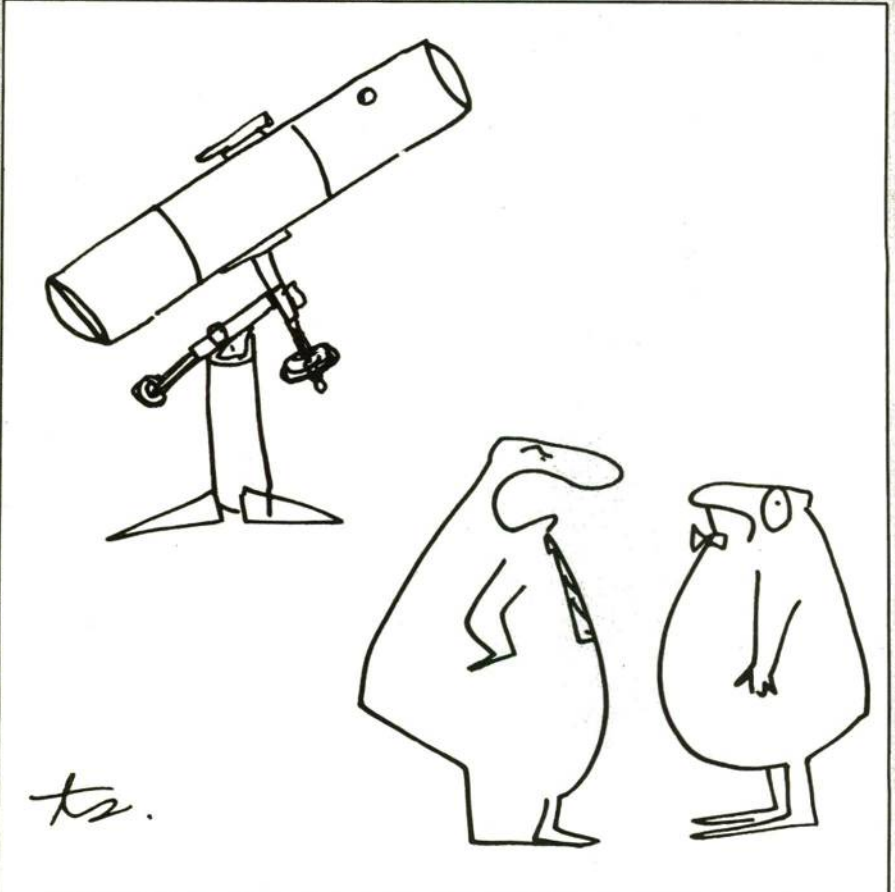

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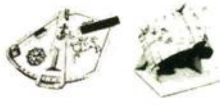

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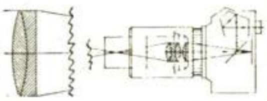

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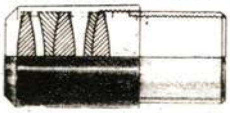

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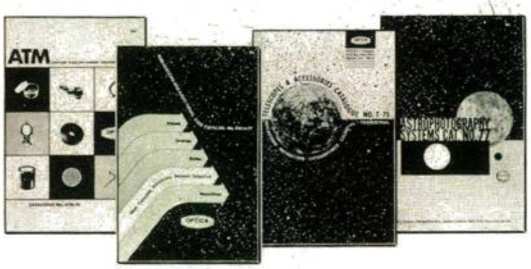

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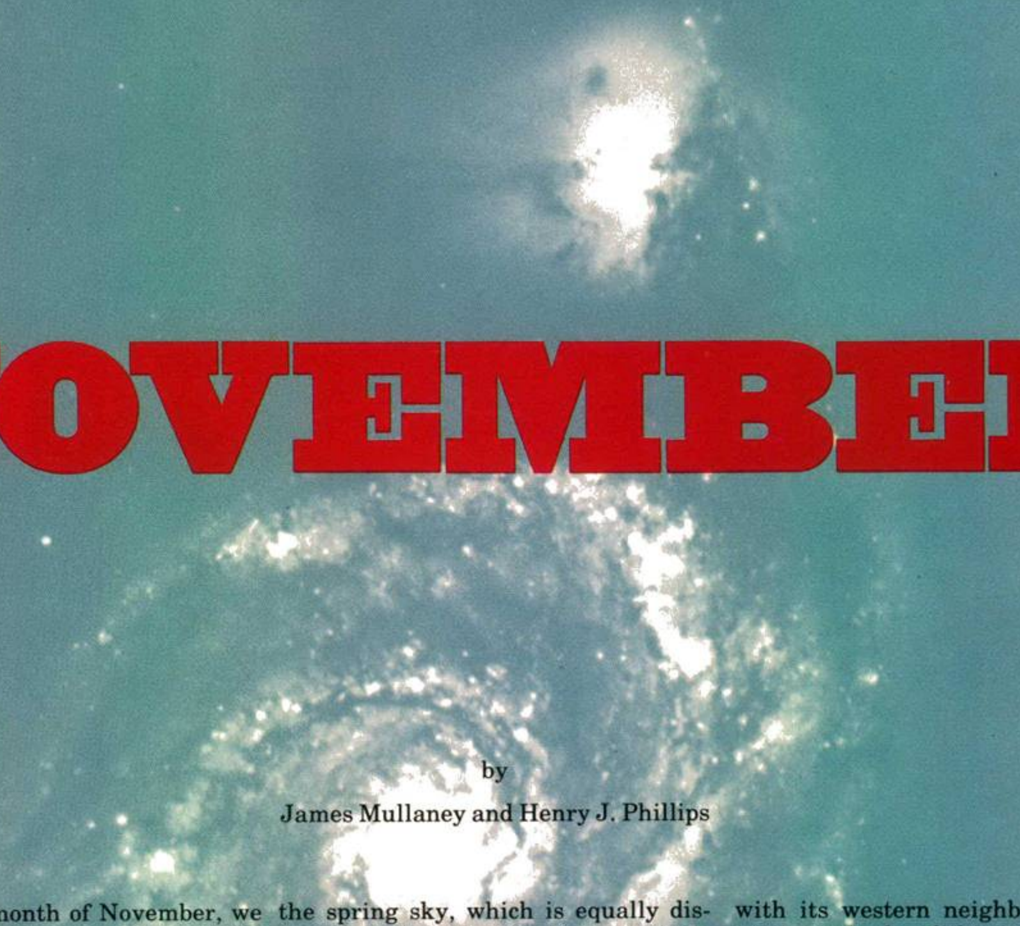


NOVEMBER

by

James Mullaney and Henry J. Phillips

During the month of November, we have an unusual perspective of the Milky Way. It stretches across the sky from west to east, passing almost overhead for observers in North America. Almost all the bright stars and interesting objects visible this month are lined up along this cloudy band of the galaxy, from the summer triangle (only now finally setting in the west), through the cluster-laden stretches of Cepheus, Cassiopeia and Perseus, down to winter's Great Circle of first magnitude stars beginning to poke above the eastern horizon.

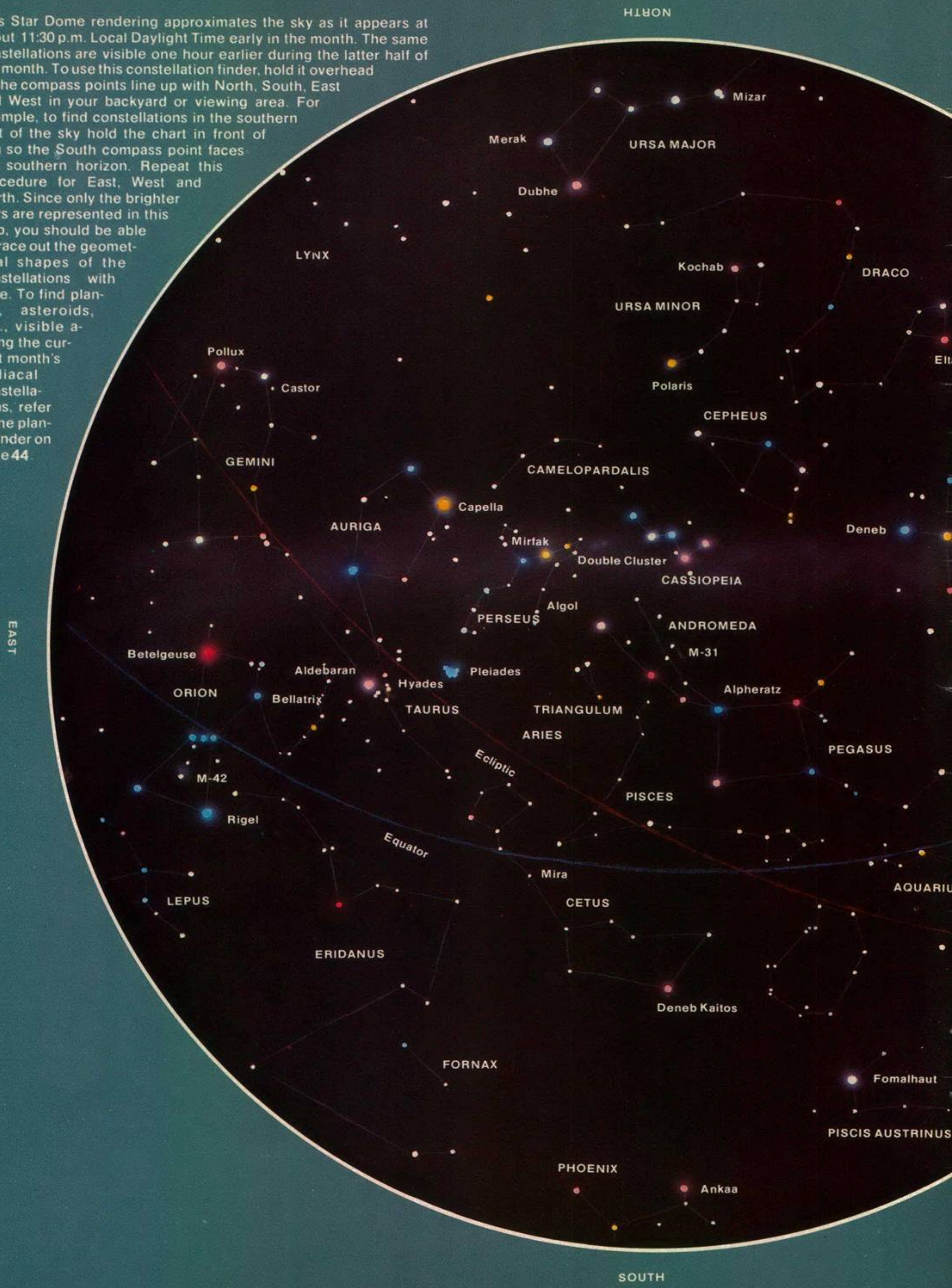
By contrast, most of the sky to the south contains only dim stars and faint star patterns. The few bright stars that are visible in this area — such as Fomalhaut and Deneb Kaitos — stand out because of their isolation and appear much brighter than they would in more crowded parts of the heavens. In the fall, we are looking away from the plane of the galaxy; the south galactic pole is located in Sculptor, just south of Cetus. But even the spring sky, which is equally distant from the galactic plane, contains a larger number of bright stars. One possible explanation for fall's dimness may be that our sun is closer to the "southern" edge of the spiral arm in which it is located than the "northern", so that fewer stars intervene between us and intergalactic space when we face "south".

Whatever the reason, the constellations in the southern autumn sky are large, spreading and faint. Aquarius, Pisces, Cetus and Eridanus all rank among the very largest constellations, and all contain vast blank areas with little or nothing of interest. Even the two "modern" constellations in this area (Sculptor and Fornax) are among the biggest in that category, and each has no star brighter than fourth magnitude!

Just barely climbing over the horizon for most observers in the United States (but more easily visible from southern areas of the country) is the constellation Phoenix — along with its western neighbor Grus, the most northerly of the star groups introduced in 1603 by Johann Bayer. From places where it climbs higher in the sky, Phoenix is quite easy to see, since it does contain some bright stars. Its most prominent configuration is a triangle composed of Alpha, Beta and Gamma Phoenicis — all third magnitude or brighter. Alpha (whose proper name is Ankaa) shines at magnitude 2.4, and if you have a clear horizon to the south, you can locate it very easily as follows.

Begin with Polaris, the north star. Draw a line from Polaris to the star at the westernmost tip of the "W" in Cassiopeia. Continue this line through the two stars that form the eastern (left) edge of the Great Square of Pegasus, and extend the line southward to Iota (ι) Ceti, the star just northwest of Deneb Kaitos. Finally, bring the line down to the southern horizon, where it will hit Ankaa. Extending a line across the sky in this manner allows you not only to find

This Star Dome rendering approximates the sky as it appears at about 11:30 p.m. Local Daylight Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page **44**.


NORTH
Mizar
Merak
URSA MAJOR
Dubhe
LYNX
Kochab
DRACO
URSA MINOR
Pollux
Castor
Polaris
Elt
CEPHEUS
GEMINI
CAMELOPARDALIS
Capella
AURIGA
Deneb
Mirfak
Double Cluster
CASSIOPEIA
Algol
PERSEUS
ANDROMEDA
EAST
Betelgeuse
M-31
Aldebaran
Pleiades
Hyades
ORION
Bellatrix
Alpheratz
TAURUS
TRIANGULUM
ARIES
PEGASUS
Ecliptic
M-42
PISCES
Rigel
Equator
Mira
AQUARIU
LEPUS
CETUS
ERIDANUS
Deneb Kaitos
FORNAX
Fomalhaut
PISCIS AUSTRINUS
PHOENIX
Ankaa
SOUTH

Map Centered on 40° North Latitude

HERCULES
Vega
LYRA
CYGNUS
DELPHINUS
Altair
AQUILA
EQUULEUS
CAPRICORNUS
WEST

Map by Adolf Schaller

Ankaa, but also to trace out (very nearly) the *zero hour circle* of declination — the sky's "Greenwich meridian", from which all celestial longitude is measured.

The stars of Phoenix represent exactly what the constellation's name says: the phoenix, a magical bird found in Arabian and Russian folklore. Different versions of the phoenix's story give varying details, but they agree in essentials. According to one legend, there was only one phoenix in the world. Every 100 years it would prepare a nest of spices and herbs, which the heat of the sun would set aflame. The phoenix allowed itself to be consumed in the blaze, and from its ashes a phoenix would arise to repeat the entire cycle. In this way, the bird achieved immortality — although it's never quite clear from the legend whether the same phoenix or a new one rose from the ashes.

The phoenix's life cycle has been variously given as 1, 10, 100, or 500 years, and some stories tell that there was more than one of these strange birds. The feathers of the phoenix were endowed with magical properties, and were always favorite prizes for adventurers. In the **Thousand and One Nights**, Sindbad the sailor was ordered to bring back three feathers from the tail of the phoenix in order to win the hand of the princess who became his wife.

Stories of this remarkable bird penetrated Europe during the Middle Ages, along with much other Arabian knowledge and lore. The image of the eternally resurrected phoenix became a popular metaphor for the resurrection of Christ in the medieval church.

Slavic and Russian mythologists transformed the phoenix into the firebird, which had many of the same properties as its Arabian counterpart — but with the added hazard that its feathers were actually made of fire! These feathers were remarkably effective good luck charms; in Stravinsky's ballet **The Firebird** (based on Russian legends), the bird's feather proves of considerable value in killing an evil monster and rescuing several imprisoned princesses.

Before Bayer published his atlas containing the constellation Phoenix, its stars were thought by Arabian astronomers to represent a boat — an object certainly in keeping with other groups in this area, most of which have "watery" designations. One of the most important of these is Pisces the fishes — important not for the number or brightness of its stars (it has none that are particularly luminous), but for its special position on the ecliptic. Pisces holds the vernal equinox within its borders. However, the constellation did not always hold such an exalted position; before precession moved the equinoctial point out of its eastern neighbor Aries, Pisces was no more than a nondescript zodiacal constellation — and the dimmest of them all, except for Cancer.

There are two fishes in Pisces: the Western and the Northern. Between them run two dim lines of stars that meet at the fourth magnitude star Al Rischa (Alpha Piscium). This star symbolized a knot, for the two streams of stars were always drawn as two cords, ropes or ribbons that held the two fish by their tails and were knotted together at Al Rischa. Exactly why the fishes should have been tied together has gone universally unexplained, but you'll find Pisces so represented in nearly every atlas or drawing you can find. The only alternative drawing we've seen is one in which the two ribbons of stars were shown as two streams of water pouring from the mouths of the fishes and splashing against the neck of Cetus at Al Rischa. Such a drawing, though, is as farfetched as those which show Piscis Austrinus (the southern fish) swallowing the stream of water spilled from the jug of Aquarius — and for the same reason (see Star Dome, October 1977).

When Pisces crosses the meridian on November evenings, we know that winter is imminent. Already Orion and Taurus are waging their annual battle as they climb high in the east, while Auriga, Gemini and Perseus cluster around the pair like spectators at a bullfight. The dim, lonely fishes serve notice of the approaching end of another year.

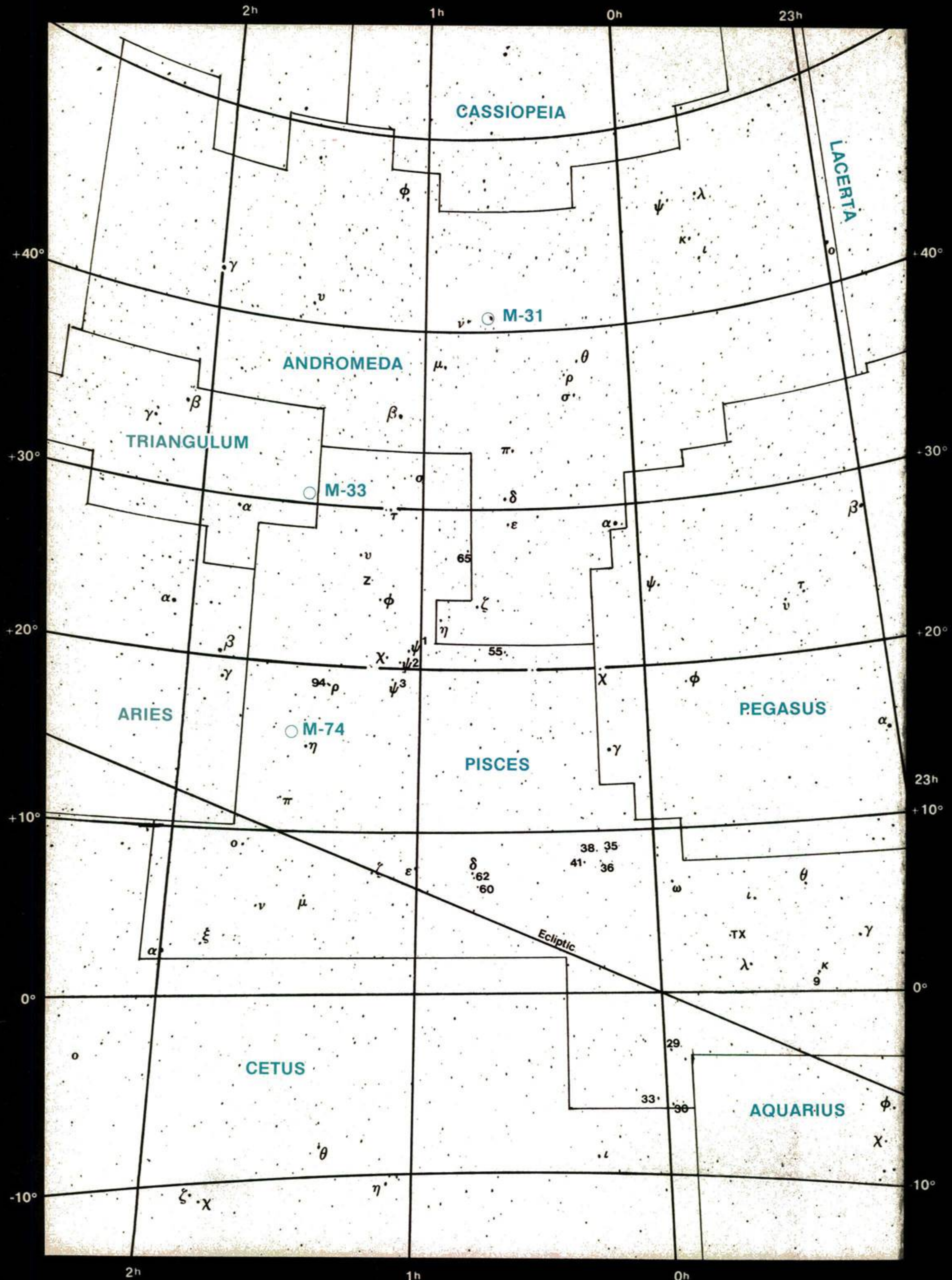
Close-Up

Pisces Region

"A dull region, containing some good telescopic objects" was Webb's summation of the inconspicuous zodiacal constellation Pisces. The group's most obvious feature is the circlet of stars situated beneath the Great Square of Pegasus, representing the western fish. Olcott referred to this neat asterism as "an attractive naked eye sight" — and so it is. The circlet is also a good subject for binocular viewing.

A string of fourth and fifth magnitude gems connects the circlet to Alpha Piscium, the constellation's brightest star. From this luminary another faint stream of stars extends upward in the sky toward the northern fish, which is located just below Beta (β) Andromedae. The northern fish is much less definite in form than its western counterpart, and you'll need a dark moonless evening to trace out Pisces in its entirety.

Pisces' chief claim to fame is the location within its borders of the ver-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1h
0h
23h
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ANDROMEDA
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TRIANGULUM
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M-33
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94 ρ
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ARIES
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M-74
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62
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Photograph by Brad Wallis and Robert Provin/ Map by Henry J. Phillips nal (spring) equinox, otherwise known as the "First Point of Aries". The precessional motion of Earth has carried the equinox from that constellation to its present site in Pisces. The equinoctial point is, alas, unmarked by any bright star; it is about three degrees north of 29 Piscium.

Because of its dimness, Pisces is seldom visited by celestial treasure hunters in their nightly explorations. Yet there are many wonders to be seen here — even with binoculars and wide field telescopes. Barns described this month's region as "rather barren of the more commanding phenomena, but fruitful of interest in vicinity of Chi, and especially following Eta." Chi (χ) Piscium is notable for the striking proximity of three stars in a line [Psi (ψ) 1, 2 and 3 Piscium] in what Barns called an "amazing sequence".

Other binocular sights are the apparent doubles formed by Rho (ρ) and 94 Piscium (dubbed a "splendid pair" by Webb), and Kappa (κ) and 9 Piscium (sometimes referred to as Kappa 1 and Kappa 2). Olcott noted, "The region about Kappa is particularly beautiful." And returning to Barns, we are advised that "superb sweeping" is to be found about Delta (δ), with 60 and 62 Piscium in the field, and that the grouping of stars 35, 36, 38 and 41 Piscium is a "region of splendors"!

One final target for binocular users is the strongly tinted variable star TX (or 19) Piscium. The easternmost member of the circlet, the star's reddish hue is obvious with even the slightest optical aid, and is sure to stop you in your tracks as you sweep this area of the sky.

Alpha (α) Piscium

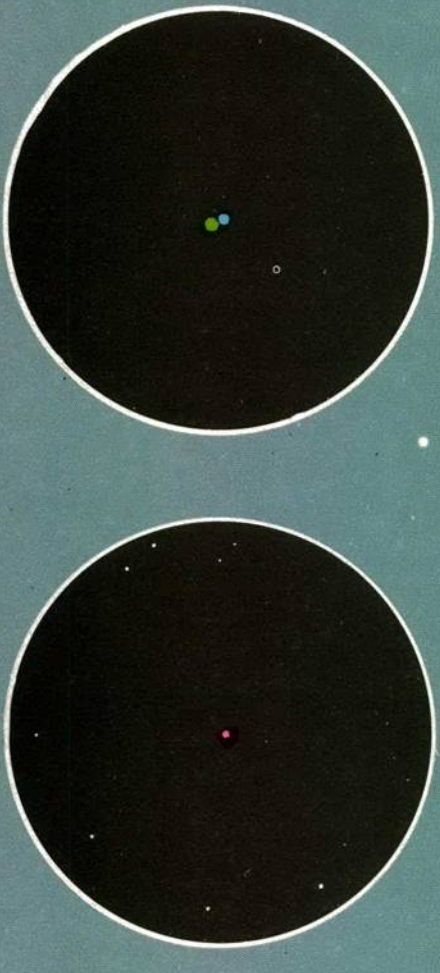
Many lovely double stars for small telescopes adorn the Pisces region; some of the more attractive specimens are listed in our table of selected objects. The most fascinating — and, at the same time, most challenging — of these stellar duos is fourth magnitude Alpha Piscium, located south of Aries in the middle of nowhere. To find it, draw a line from Beta through Gamma (γ) Arietis, and extend this line about 16 degrees southward; it will reach a point just west of Alpha's position.

Here we find glowing fourth and fifth magnitude suns a scant two seconds of arc apart, forming a tight pair for small apertures. Alpha is a long period binary requiring an estimated 720 years to make a circuit. The gap between the stars has been closing since 1700, when the separation was just over four seconds and Alpha was an easy object. Today the space between the two has narrowed to 1.8 seconds, and will continue to close to a minimum just under one second about the year 2075 A.D. The companion now lies slightly south of west of the primary and is moving counterclockwise on the sky, so its position angle is decreasing.

Twenty years ago when Alpha's separation was 2.5 seconds at position angle 306 degrees, the pair was considered a test for a two inch scope. Presently the stars are closing beyond the reach of 2.4 and 3 inch refractors, though the latter can still split them at high power on a steady night. When seeing is less than average, the components are blended and Alpha looks like some eerie cosmic egg! The view in 6 to 10 inch instruments at high magnifications is stunning, as hinted in our drawing made from an eight inch reflector at 300 power.

It's always fun to see just how small a telescope is needed to split a close pair like Alpha Piscium. Sky conditions, optical quality and training of the observer's eye all come into play here. If you own a large telescope, try masking it down using cardboard stops in one inch steps to an effective aperture of an inch or less. (The openings in these masks should be centered on-axis for a refractor and off-axis with a reflector or catadioptric instrument, to avoid the secondary obstruction.) As we have shown before in Star Dome, this technique strikingly alters the appearance of star images as aperture decreases, because of diffraction effects. In the case of close doubles like Alpha, decreasing resolution transforms them from a cleanly split set of stars to merging and blended blobs, and finally an unresolved ellipse — all within a matter of seconds!

Splitting Alpha Piscium is only part of the challenge offered by this lonesome pair. Perhaps more of a feat for most observers is pinning down the tints of the components, for the colors are extremely subtle, with different apertures and instruments giving various impressions. We are haunted by the presence of a definite but elusive contrast in heavenly hues here.



Top: The tints of the components of the double star Alpha Piscium are among the most elusive in the sky; indeed, many observers have been content to call the stars white. Our drawing, which shows the view through an eight inch reflector at 300 power, gives the double's colors as blue and green — hues seen by most of the classic observers. The field of view is 10 minutes of arc. Bottom: TX Piscium (also know as 19 Piscium) is a variable star of intense red hue. TX does not vary widely in brightness, so it is always available to the observer who wants to see its vivid color, obvious even in a three inch refractor at 40 power as shown here. The field of view is 1.5 degrees. Drawings by James Mullaney.

Selected Objects — Pisces Region

Object	Type	Mag.	Size/ Sep.	R.A. (1950)	Dec.
* TX Piscium	V:?	5-6	—	23^h44^m	+03°13'
55 Piscium	★2	5.6,8.8	7"	00^h37^m	+21°10'
65 Piscium	★2	6.3,6.3	4.4"	00^h47^m	+27°26'
ψ^1(Psi 1)	★2	5.6,5.8	30"	01^h03^m	+21°12'
ζ(Zeta)	★2	5.6,6.5	24"	01^h11^m	+07°19'
Z Piscium	$V{:}144^d$	7.0-7.9	—	01^h13^m	+25°30'
* M-74	Sp	10	11'x9'	01^h34^m	+15°32'
*α (Alpha)	★2	4.3,5.2	1.8"	01^h59^m	+02°31'

*Detailed in Close-Up

★2 = Double Star
$V{:}\#^d$= Variable Star, Period
Sp = Spiral Galaxy

Mag. = Magnitude
Sep. = Separation

Most double star viewers see the primary as greenish and the companion as bluish, though both stars may look white to you on first inspection. Flammarion included Alpha in his list of the 25 best doubles and described it as "blanches" (white). It appears as a runner-up in Pickering's roster under the heading "White Doubles".

Olcott, however, recorded Alpha as green and blue, and Norton, pale green and blue. Bernhard, Bennett and Rice noted "color contrast remarkable" and suggested shades of green-white and blue or brown! Muirden said "curious tints, somewhat greenish".

The best indication of the confusion attending Alpha's tints can be found in Webb's detailed description of more than a century ago: "Pale green, blue, 1834, 1838, 1850; Struve ditto 1831; Dawes very white, white, 1846; Fletcher both yellow, 1851; Dembowski white, ashy white, 1854; Piazzi, Smyth both white, 1856; so Dunner 1868, 1871, 1872. I found the contrast certain, but (companion) troublesome as to color, usually ruddy or tawny, sometimes bluish. 1855, 3.7 inch (refractor) I noted it pale yellow, brown yellow, 'quite satisfactory'; in 1860, 5.5 inch (refractor) pale yellow, tawny or fawn colored, 'certain'; in 1862 (companion) bluish?? no strong contrast; in 1871, 9 inch speculum (reflector) brownish; at first fancied bluish." No wonder that early observers suspected double star colors of changing with time!

Although reflectors generally have a slight edge in critical color discrimination, the sizable diffraction disks produced by small refractors at high powers make subtle tints easier to see by spreading the light over a greater area of the retina. The alternative method of doing the same thing is to slightly defocus the image at the telescope. Unfortunately, this will not work in the case of close pairs like Alpha, since the star images immediately merge and "contaminate" each other.

Interestingly, both of Alpha's suns are of the same spectral class — A2. The late Harvard astronomer Donald Menzel considered stars of this type to be green in color. Both components also have an unseen spectroscopic companion in orbit about them, which could result in unusual color blends. This complex quadruple system lies about 130 light-years from us.

Perhaps the best summary description of Alpha's enigmatic hues is that given by Barns: "Weird coloring!" What incredible cosmic coloration does your telescope reveal this duo to have?

TX Piscium

After a long session at the eyepiece puzzling over the shades of our first offering, we suggest you have a go at an object that leaves no doubt at all about its cast. This is the variable star TX Piscium, situated in the circlet of Pisces and sometimes labeled 19 on star charts.

TX is a pulsating sun that is classified as irregular, since no definite period has yet been found. A great deal of uncertainty exists about its actual visual magnitude. Of the many references consulted each month in the preparation of Star Dome, *none* could provide a reliable figure for this object's range in brightness as seen with the eye. Only the blue photographic magnitude spread has apparently been determined for TX, and this is consistently given as 6.9 to 7.7. A red star like TX is generally at least a full magnitude brighter visually than photographically, and we find the best value for its range to be from fifth to sixth magnitudes as judged by the eye.

Thus, as Brown put it, TX "is bright enough anytime for a good look." He went on to say "the color is excellent" — and so it is! This object's spectral class is N0, and its deep reddish orange glow is apparent in all apertures.

Given a wide enough telescopic field, TX will be found situated in its own "circlet" of faint stars, as shown in our sketch with a three inch refractor at 40 power and a 1.5 degree-of-arc view. This beautiful crimson gem looks like a glowing cosmic ember at the center of a heavenly campfire!

Pickering included only five red stars over the entire sky in his famous list of showpieces, and TX Piscium is one of them. Webb regarded it as a "magnificent object" and called attention to a curious eighth magnitude starry triangle about three degrees following and 1/2 degree south of its position.

Perhaps the strangest circumstance surrounding this object is the fact that Olcott — an avid observer of variable stars and a founder of the American Association of Variable Star Observers (AAVSO) — made no mention of TX in his classic work! The annals of observational astronomy are replete with such curiosities, adding greatly to the fascination of actual telescopic examination of the heavens. When you go to the eyepiece yourself and look with your own eyes — retracing the steps of great observers like Herschel, Webb, Barns and Olcott — can you find plausible explanations for such mysteries from out of the past?

M-74

Our final offering this month is one of the most difficult and least often viewed of all Messier's discoveries. This is M-74, the best Pisces has to offer from the flock of faint galaxies peppered throughout its confines. Lost in solitude, this object virtually cries for attention!

M-74 is a roughly circular glow measuring some 11 by 9 minutes in size and having an integrated brightness equal to that of a 10.2 magnitude star. It's much too faint for finders and must be swept for with a low power eyepiece on the telescope itself.

Fortunately, this galaxy is easy to locate. It lies in a profound darkness just 1.5 degrees east and slightly north of third magnitude Eta (η) Piscium. A line from Alpha through Beta Arietis points directly at Eta, allowing a quick "key in" to the region containing M-74. Both star and galaxy fit nicely in a three degree field, as seen in a four inch RFT at 15 power.

Some idea of just how somber this face-on spiral is in small telescopes can be gathered from the fact that neither Webb nor Olcott included M-74 in their surveys. Norton tersely stated, "faint and elusive". Even Barns failed us here, for he included this object in his book without description except to erroneously log it as a star cluster!

We must turn to a modern observer — Messier authority Holyoke — for some account of this object. "This spiral galaxy was the most difficult of all the Messier objects for me to find with a three inch telescope. It is large but, like M-101, its surface brightness is low. A six inch shows it with no trouble at all, but it is best at low powers."

Actually, M-74 can be glimpsed with a 2.4 inch refractor at 35 power on a dark night using averted vision; indeed, you can see all the Messier objects with just a two inch scope. But to appreciate this object's "role" as a galaxy, eight inch and larger scopes are needed, as well as a good observing site away from city lights and pollution. Such instruments reveal a small nucleus surrounded by a faint circular nebulosity which may occasionally break into tantalizing suggestions of spiral structure.

M-74 is invariably one of the last Messier objects to be bagged by observers hunting down the entire list of nebulae and clusters. If you're just embarking on this quest, you might do well to go after this one first while it is well placed for viewing on November's meridian. After M-74, the rest should be easy!

We view the feeble glow of this graceful spiral across the intergalactic void as "through a glass darkly", its glory dimmed by vast distance. This ghostly star city in the night has a decidedly dreamlike look to it at the eyepiece, bringing to mind something John Lear once said: "Man is a sun-roused dreamer, enroute to tomorrow, a place he spins out of himself across the emptiness of time from gossamers of his imaginings."

Celestron 90
Maksutov-Cassegrain Telescope

C90 Astro telescope. $495.

C90 Telephoto. $245.

C90 Spotting Scope. $295.

At last! A quality telescope designed with the beginner in mind and priced so that he can afford it. It's the Celestron 90 and with it you'll be able to study lunar craters, the rings of Saturn, the cloud belts and moons of Jupiter, and scores of nebulae and galaxies. During the day you'll see bees buzzing in flowers 20 feet away, observe birds feeding their young in nests 50 feet away, identify airliners miles away, and much more.

The Celestron 90 has the same quality and features that have made Celestron telescopes world famous:

Portability: The C90 is the ultimate in portability. With its single-fork mounting and drive, it swings down to a compact 7" x 7" x 13" and weighs a mere 8 lbs (approx).

Superb Optics: A full 90mm aperture (3.55 inches) f/11 Maksutov telescope worthy of the Celestron name. The optics are permanently collimated and fully baffled. No other commercially-made Maksutov telescope has the primary mirror as well as the secondary mirror fully baffled. Its closed-tube design eliminates image-degrading tube currents and keeps the optics free of dust and other contaminants.

Ease of Operation: Place the C90 and its stable mount on a table and it's ready to use. Focus quickly and accurately by rotating the telescope tube. Increase the magnification from 55X to 140X or 200X by simply inserting the barlow lens in the appropriate position. The controls are always at your finger tips. Mount it on the optional equatorial wedge and the built-in tracking system will follow celestial objects indefinitely.

Versatility: The C90 is much more than just a quality astronomical telescope. It's also the ideal telescope for birdwatching, wildlife/nature viewing, or general spotting. The tube may be easily removed from the mount and attached to your photo tripod. Inexpensive adapters quickly couple your 35mm SLR camera to the scope and give you a 20X telephoto lens.

Celestron 90 Specifications

Optics	Maksutov-Cassegrain
Aperture	90mm (3.55")
Focal length	1000mm (40 inches)
Photographic Speed	f/11
Photographic Power	20x
Resolution (Dawes limit)	1.3 arc seconds (120 lines/mm)
Visual Stellar Magnitude Limit	12
Light Grasp (Compared to unaided eye)	160x
Image Scale	1.43°/inch
Illuminated Field	1.5" circle (3" behind cell)
Near Focus (approx.)	15 feet
Secondary Obstruction	1⅜" (15%)
Finder Scope	5x - 24mm
Slow-Motion Controls	Manual (both axes)
Electric Drive	3 watts, 110V 60Hz
Drive Gear Diameter	4½ inch spur
Setting Circle Diameter	R.A. 6¼ inches (Driven) Dec: 4 inches
Color	Orange and Brown
Eyepiece	18mm Kellner, 24.5mm O.D.
Barlow	2.5x
Tube Size	5" Dia.x 8" Long
Weight	3# (approx)
Telescope Size (Swung down)	7" x 7" x 13"
Weight	8# (approx)
Telephoto Case Size	6½" x 8½" x 10½"
Weight	3#
Telescope Case Size	8½" x 8½" x 15"
Weight	3½#

Celestron

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